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Code of practice for instrumentation in process control systems: installation design and practice

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Summary of pages

This document comprises a front cover, an inside front cover, pages i to vi, pages 1 to 272, an inside back cover and a back cover.

Foreword

Publishing information

This British Standard is published by BSI and came into effect on 1 January 2009. It was prepared by Technical Committee GEL/65, *Measurement and control*. A list of organizations represented on this committee can be obtained on request to its secretary.

Supersession

This British Standard supersedes BS 6739:1986, which is withdrawn.

Information about this document

This is a full revision of the standard, and introduces the following principal changes:

- existing recommendations brought up to date to reflect changes in workplace practice and technology since 1986;
- new recommendations added to take into account technology introduced since 1986;
- guidance on legislation brought up to date to reflect regulations and directives introduced since 1986.

Use of this document

As a code of practice, this British Standard takes the form of guidance and recommendations. It should not be quoted as if it were a specification and particular care should be taken to ensure that claims of compliance are not misleading.

Any user claiming compliance with this British Standard is expected to be able to justify any course of action that deviates from its recommendations.

BSI permits the reproduction of the specimen check sheets in Annex C (Figures C.1 to C.5). This reproduction is only permitted where it is necessary for the user to record findings on the check sheets during each application of the standard.

Presentational conventions

The provisions in this standard are presented in roman (i.e. upright) type. Its recommendations are expressed in sentences in which the principal auxiliary verb is "should".

Commentary, explanation and general informative material is presented in smaller italic type, and does not constitute a normative element.

Contractual and legal considerations

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Compliance with a British Standard cannot confer immunity from legal obligations.

1 Scope

NOTE The recommendations given in this British Standard are based on the assumption that all instruments will have been specified and all instrument panels will have been designed.

This British Standard gives recommendations for, and guidance on, the design for the installation of instrumentation of measurement and control systems in the process industry, and the implementation and commissioning of this installation. It is intended to be used as a manual of good practice on the site and also to assist those who design the installation.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

Standards publications

BS 759-1, *Valves, gauges and other safety fittings for application to boilers and to piping installations for and in connection with boilers – Part 1: Specification for valves, mountings and fittings*

BS 1363-1, *13 A plugs, socket-outlets and adaptors – Specification for rewirable and non-rewirable 13 A fused plugs*

BS 3680 (all parts), *Measurement of liquid flow in open channels*

BS 4278, *Specification for eyebolts for lifting purposes*

BS 4727 (all parts), *Glossary of electrotechnical, power, telecommunication, electronics, lighting and colour terms*

BS 5308 (both parts), *Instrumentation cables*

BS 5499-1, *Graphical symbols and signs – Safety signs, including fire safety signs – Part 1: Specification for geometric shapes, colours and layout*

BS 5839-1, *Fire detection and fire alarm systems for buildings – Part 1: Code of practice for system design, installation, commissioning and maintenance*

BS 6346, *Electric cables – PVC insulated, armoured cables for voltages of 600/1000 V and 1900/3300 V*

BS 6423, *Code of practice for maintenance of electrical switchgear and controlgear for voltages up to and including 1 kV*

BS 7430, *Code of practice for earthing*

BS 7454, *Method for calculation of thermally permissible short-circuit currents, taking into account non-adiabatic heating effects*

BS 7671, *Requirements for electrical installations – IEE Wiring Regulations – Seventeenth edition*

BS 8444-3, *Risk management – Part 3: Guide to risk analysis of technological systems*

BIP 3081, *Legal admissibility collection (BIP 0008 and BIP 0009)* [1)]

1) BIP 3081 comprises BIP 0008, *Code of practice for legal admissibility and evidential weight* (in three parts) and BIP 0009, *Code of practice for legal admissibility and evidential weight – Compliance workbook* (in three parts).

PD 5304, *Guidance on safe use of machinery*

PD 5500, *Specification for unfired fusion welded pressure vessels*

BS EN 207, *Personal eye-protection – Filters and eye-protectors against laser radiation (laser eye-protectors)*

BS EN 614-1, *Safety of machinery – Ergonomic design principles – Part 1: Terminology and general principles*

BS EN 1127 (both parts), *Explosive atmospheres – Explosion prevention and protection*

BS EN 10216-1, *Seamless steel tubes for pressure purposes – Technical delivery conditions – Part 1: Non-alloy steel tubes with specified room temperature properties*

BS EN 10217-1, *Welded steel tubes for pressure purposes – Technical delivery conditions – Part 1: Non-alloy steel tubes with specified room temperature properties*

BS EN 10217-7, *Welded steel tubes for pressure purposes – Technical delivery conditions – Part 7: Stainless steel tubes*

BS EN 12449, *Copper and copper alloys – Seamless, round tubes for general purposes*

BS EN 13284-1, *Stationary source emissions – Determination of low range mass concentration of dust – Part 1: Manual gravimetric method*

BS EN 13284-2:2004, *Stationary source emissions – Determination of low range mass concentration of dust – Part 2: Automated measuring systems*

BS EN 13463 (all parts), *Non-electrical equipment for potentially explosive atmospheres*

BS EN 14181:2004, *Stationary source emissions – Quality assurance of automated measuring systems*

BS EN 15259, *Air quality – Measurement of stationary source emissions – Requirements for measurement sections and sites and for the measurement objective, plan and report*

BS EN 15267-3, *Air quality – Certification of automated measuring systems – Part 3: Performance criteria and test procedures for automated measuring systems for monitoring emissions from stationary sources*

BS EN 50173 (all parts), *Information technology – Generic cabling systems*

BS EN 50174 (all parts), *Information technology – Cabling installation*

BS EN 50178, *Electronic equipment for use in power installations*

BS EN 50262, *Cable glands for electrical installations*

BS EN 50288-7, *Multi-element metallic cables used in analogue and digital communication and control – Part 7: Sectional specification for instrumentation and control cables*

BS EN 60079 (all parts), *Electrical apparatus for explosive gas atmospheres*

BS EN 60204-1, *Safety of machinery – Electrical equipment of machines – Part 1: General requirements*

BS EN 60205, *Calculation of the effective parameters of magnetic piece parts*

BS EN 60309 (all parts), *Plugs, socket-outlets and couplers for industrial purposes*

BS EN 60529, *Specification for degrees of protection provided by enclosures (IP code)*

BS EN 60584 (all parts), *Thermocouples*

BS EN 60751, *Industrial platinum resistance thermometer sensors*

BS EN 60801-2, *Electromagnetic compatibility for industrial-process measurement and control equipment – Part 2: Electrostatic discharge requirements*

BS EN 60825 (all parts), *Safety of laser products*

BS EN 60950 (all parts), *Information technology equipment – Safety*

BS EN 61010 (all parts), *Safety requirements for electrical equipment for measurement, control, and laboratory use*

BS EN 61131-2, *Programmable controllers – Part 2: Equipment requirements and tests*

BS EN 61241 (all parts), *Electrical apparatus for use in the presence of combustible dust*

BS EN 61285, *Industrial-process control – Safety of analyser houses*

BS EN 61326 (all parts), *Electrical equipment for measurement, control and laboratory use – EMC requirements*

BS EN 61386-1, *Conduit systems for cable management – Part 1: General requirements*

BS EN 61508 (all parts), *Functional safety of electrical/electronic/ programmable electronic safety-related systems*

BS EN 61511 (all parts), *Functional safety – Safety instrumented systems for the process industry sector*

BS EN 61800-5-1, *Adjustable speed electrical power drive systems – Safety requirements – Part 5-1: Electrical, thermal and energy*

BS EN 62061, *Safety of machinery – Functional safety of safety-related electrical, electronic and programmable electronic control systems*

BS EN 62262, *Degrees of protection provided by enclosures for electrical equipment against external mechanical impacts (IK code)*

BS EN ISO 1461, *Hot dip galvanized coatings on fabricated iron and steel articles – Specifications and test methods*

BS EN ISO 4126-1, *Safety devices for protection against excessive pressure – Part 1: Safety valves*

BS EN ISO 5167 (all parts), *Measurement of fluid flow by means of pressure differential devices inserted in circular cross-section conduits running full*

BS EN ISO 11064 (all parts), *Ergonomic design of control centres*

BS EN ISO 11252, *Lasers and laser-related equipment – Laser device – Minimum requirements for documentation*

BS EN ISO 13406, *Ergonomic requirements for work with visual display based on flat panels*

BS ISO 9096, *Stationary source emissions – Manual determination of mass concentration of particulate matter*

BS ISO 10155, *Stationary source emissions – Automated monitoring of mass concentrations of particles – Performance characteristics, test methods and specifications*

BS ISO 10396, *Stationary source emissions – Sampling for the automated determination of gas emission concentrations for permanently-installed monitoring systems*

BS ISO 14164, *Stationary source emissions – Determination of the volume flowrate of gas streams in ducts – Automated method*

BS ISO 15489-1, *Information and documentation – Records management – Part 1: General*

BS ISO/IEC 27001, *Information technology – Security techniques – Information security management systems – Requirements*

BS IEC 61000-4-2, *Electromagnetic compatibility (EMC) – Part 4-2: Testing and measurement techniques – Electrostatic discharge immunity test – Basic EMC publication*

BS IEC 61513, *Nuclear power plants – Instrumentation and control for systems important to safety – General requirements for systems*

DD CEN/TS 15675, *Air quality – Measurement of stationary source emissions – Application of EN ISO/IEC 17025:2005 to periodic measurements*

DD CLC/TS 61643-12, *Low-voltage surge protective devices – Surge protective devices connected to low-voltage power systems – Part 12: Selection and application principles*

DD CLC/TS 61643-22, *Low-voltage surge protective devices – Surge protective devices connected to telecommunications and signalling networks – Part 22: Selection and application principles*

PD CLC/TR 50404, *Electrostatics – Code of practice for the avoidance of hazards due to static electricity*

PD IEC/TR 60825-14, *Safety of laser products – Part 14: A user's guide*

ISO/IEC 24702, *Information technology – Generic cabling – Industrial premises*

IEC 61784-5, *Digital data communication for measurement and control – Part 5: Installation profiles for communication networks in industrial control systems*

IEC 61918, *Digital data communications for measurement and control – Profiles covering installation practice for fieldbus communications media within and between the Automation Island*

Other publications

INTERNATIONAL COMMISSION ON NON-IONIZING RADIATION PROTECTION. Guidelines on limits of exposure to ultraviolet radiation of wavelengths between 180 nm and 400 nm (incoherent optical radiation). *Health physics*, 2004, Volume 87 (2), pp. 171–186.[2)]

INTERNATIONAL COMMISSION ON NON-IONIZING RADIATION PROTECTION. Revision of the guidelines on limits of exposure to laser radiation of wavelengths between 400 nm and 1.4 μm. *Health physics*, 2000, Volume 79 (4), pp. 431–440.[2)]

2) Available for downloading from http://www.icnirp.de/PubOptical.htm.

INTERNATIONAL COMMISSION ON NON-IONIZING RADIATION PROTECTION. Guidelines on limits of exposure to broad-band incoherent optical radiation (0.38 to 3 μm). *Health physics*, 1997, Volume 73 (3): pp. 539–554.[2)]

INTERNATIONAL COMMISSION ON NON-IONIZING RADIATION PROTECTION. Guidelines on UV radiation exposure limits. *Health physics*, 1996, 71 (6): p. 978.[2)]

INTERNATIONAL COMMISSION ON NON-IONIZING RADIATION PROTECTION. Guidelines on limits of exposure to laser radiation of wavelengths between 180 nm and 1 mm. *Health physics*, 1996, Volume 71 (5): pp. 804–819.[2)]

INTERNATIONAL COMMISSION ON NON-IONIZING RADIATION PROTECTION. Proposed change to the IRPA 1985 guidelines on limits of exposure to ultraviolet radiation. *Health physics*, 1989, Volume 56 (6): pp. 971–972.[2)]

INTERNATIONAL COMMISSION ON NON-IONIZING RADIATION PROTECTION. Guidelines on limits of exposure to ultraviolet radiation of wavelengths between 180 nm and 400 nm (incoherent optical radiation). *Health physics*, 1985, Volume 49 (2): pp. 331–340.[2)]

3 Terms, definitions and abbreviations

3.1 Terms and definitions

For the purposes of this British Standard, the terms and definitions given in BS 4727 and the following apply.

3.1.1 actuator
mechanism for changing a signal into a corresponding movement

3.1.2 atmospheric contamination
presence in the environment of undesirable gases, vapours or dusts that might be harmful to equipment or personnel working in that environment

3.1.3 authorized person
person authorized by management in writing to carry out certain duties and tasks on their behalf, on the understanding that the correct and appropriate procedures will be followed and standing instructions will be adhered to

3.1.4 booster
power amplifier of which the signal gain is unity

3.1.5 competent person
person who by reason of training, experience, theoretical and practical knowledge, and maturity of judgement, is able to carry out the specified duties

NOTE Competent persons need to have the necessary ability in the particular operation of the type of plant and equipment with which they are concerned, an understanding of the relevant statutory regulations, an appreciation of the hazards involved, and sufficient authority to ensure that any action which they recommend is carried out. They need to be duly authorized to undertake the work.

3.1.6 control valve
power-operated device forming a final element in an industrial process control system

NOTE It consists of a body sub-assembly containing internal means for changing the flow rate of the process fluid. The body sub-assembly is linked to one or more actuators which respond to a signal transmitted from a controlling element.

3.1.7 converter
specialized device that converts one standardized transmission signal into another

3.1.8 crash dump
information taken from a computer at or immediately after a crash, which can subsequently permit the diagnosis of the cause of the crash

3.1.9 distributed control system
system where control responsibility is divided into a variety of modules that are arranged either geographically (per unit process) or logically (control functions) around a plant so that the failure of one does not affect the operation of others

3.1.10 gas flooding system
system which in the event of smoke or fire being detected in a given area has the ability to fill that area with a fire-retardant gas

3.1.11 hysteresis
property of a device or instrument whereby it gives different output values in relation to its input values, depending on the direction sequence in which the input values have been applied

3.1.12 instrument personnel
persons who form the labour force required to install and commission instrumentation and associated pipework, equipment and services

NOTE The trades involved are likely to include pipefitters, welders, instrument mechanics and technicians, and electricians.

3.1.13 instrument supervisor
person who directs and controls the installation personnel and whose responsibility to the owner/employer includes safety matters, work progress and standards, labour discipline and industrial relations

NOTE This includes all supervisors and managers up to and including the site agent.

3.1.14 inverter
device that converts a direct current to an alternating current

NOTE This is normally employed to provide 110 V a.c. or 230 V a.c. from a battery-supplied d.c. source.

3.1.15 listing
document containing all of the codes and comments associated with a particular computer program

3.1.16 positioner
device to position an actuator in accordance with a standardized signal

NOTE The positioner compares the input signal with a mechanical feedback link from the actuator, then produces an output signal necessary to move the actuator until the position feedback corresponds with the signal value.

3.1.17 power line disturbance monitor
instrument designed to analyse and monitor various power line parameters such as frequency, r.m.s. values, transient amplitudes, duration and frequency

3.1.18 process control computer
computer that, by means of inputs from and/or outputs to a process, directly controls and/or monitors the operation of elements in the process

3.1.19 programmable multi-loop controller
controller capable of controlling two or more variables and whose control strategy is changeable by programming or software configuration

3.1.20 responsible engineer
engineer with particular responsibility for the specific project or parts of a project

3.1.21 semi-rigid coaxial cable
transmission line with two concentric conductors separated by an insulator, the outer conductor being of a solid rather than the normal braided construction resulting in a stiff though not inflexible cable

3.1.22 standby power supply
power supply that supplies the load of another power supply in the event of the other supply failing

NOTE Also known as "back-up power supply" or uninterruptible power supply (UPS).

3.1.23 star configuration
set of three or more branches connected to a common node

3.1.24 time domain reflectometer
device designed to detect and locate cable faults in coaxial and twisted pair cables

NOTE The principle involves applying a pulse to the cable under test, measuring the delay in reception of any reflections and analysing the shape of any reflected pulses.

3.1.25 transmission line
cable connecting two remote points along which electrical/ electromagnetic signals are transmitted

3.2 Abbreviations

For the purposes of this British Standard, the following abbreviations apply.

ALARP	as low as reasonably practicable
ATEX	atmosphere explosive
ATEX Regulations	Equipment and Protective Systems Intended for Use in Potentially Explosive Atmospheres Regulations 1996
BDM	basic drive module
CASS	conformity assessment for safety-related systems
CDM	complete drive module
CHIP	Chemicals (Hazardous Information and Packaging for Supply) Regulations 2002
DSEAR	Dangerous Substances and Explosive Atmospheres Regulations 2002
DTS	distributed temperature sensing
ELV	extra low voltage
ESD	electrostatic discharge
FISCO	fieldbus intrinsically safe concept

FNICO	fieldbus non-incendive concept
HMI	human–machine interface
IECEx	IEC hazardous area certification scheme
IPPC	integrated pollution prevention and control
IS	intrinsically safe
LOLER	Lifting Operations And Lifting Equipment Regulations 1998
MCB	miniature circuit breaker
MCCB	moulded case circuit breaker
MCERTS	Monitoring and Certification Scheme (of the Environment Agency)
MICC	mineral insulated copper cable
n.b.	nominal bore
o.d.	outside diameter
PDS	power drive system
PELV	protective extra low voltage
PPC	pollution prevention and control
PPE	personal protective equipment
PUWER	Provision and Use of Work Equipment Regulations 1998
PV	process variable
RCD	residual current device
Redox	reduction/oxidation
RF	radio frequency
RFID	radio frequency identification device
RIDDOR	Reporting of Injuries, Diseases and Dangerous Occurrences Regulations 1995
RoHS Regulations	Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment Regulations 2008
RPS	radiation protection supervisor
RTD	resistance temperature detector
RTTE	radio equipment and telecommunications terminal equipment
SEP	sound engineering practice
SIL	safety integrity level
SRS	safety requirements specification
SWA	steel wire armour
UPS	uninterruptible power supply
VPN	virtual private network
VA	variable area (flowmeter)
VSD	variable speed drives
WEEE	waste from electrical and electronic equipment

4 Personnel safety

*COMMENTARY ON CLAUSE **4***
The advice given in this clause is primarily concerned with those personnel who are engaged in the installation of instrumentation.

Attention is drawn to the statutory acts and regulations listed in Annex A.

All employers, self-employed and employees have a duty to be aware of all current workplace health and safety regulations that apply to them. The regulations listed or referenced in this British Standard are not necessarily exhaustive, and whilst every effort has been made to ensure that the information is up to date at the time of publication, users of this British Standard need to be aware that legislation in this area is constantly changing.

4.1 General

*COMMENTARY ON **4.1***
Under statutory regulations, employers, the self-employed, and employees have a duty to, as far as reasonably practicable, protect the general public and health, safety and welfare at work. Other regulations require action in response to particular hazards, or in industries where hazards are particularly high and might not be qualified by "as far as reasonably practicable".

Hazards are particularly high in many areas where instrument personnel will work.

*The major statutory act and regulations relevant to instrumentation installation are the Health and Safety at Work etc. Act 1974 [1], the Management of Health and Safety at Work Regulations 1999 [2] and their equivalents in Northern Ireland (see Table A.1). Guidance is given in **A.1.1**. Attention is also drawn to the Workplace (Health, Safety and Welfare) Regulations 1992 [3].*

NOTE The attention of all personnel is drawn to HSE publications L21 [4], L24 [5], INDG244 [6], INDG368 [7] and INDG259 [8].

In all workplaces the occupier should formulate a set of safety rules and site recommendations or procedures appropriate to the type of installation. These should cover the operation of equipment/plant and the work to be carried out.

Health and safety regulatory requirements and local site-related health and safety requirements should be included in site safety instructions, and it should be confirmed that all personnel working on the site have read and understood them.

A site safety brief should be prepared for all contractors entering or working on the site, and it should be confirmed that each contractor has read and understood it.

Records should be retained of compliance with regulations of all work equipment, including equipment to be installed, and tools and equipment used for installation and commissioning.

Regulations require particular competencies for some equipment and locations that instrument personnel are likely to work on or in. Records should be kept of the competencies of all personnel working on a site/installation.

4.2 Responsibilities

*COMMENTARY ON **4.2***
*Employers, the self-employed and persons in control of work premises have duties to report some work-related accidents, diseases and dangerous occurrences under the Reporting of Injuries, Diseases and Dangerous Occurrences Regulations 1995 [9]. Guidance is given in **A.1.2**.*

NOTE 1 Attention is drawn to HSE publication L73 [11], which includes the text of the Regulations and the requirements for duty holders to comply with them, including the additional provisions relating to mines, quarries and offshore workplaces.

The occupier or employer should:

- ensure that all relevant safety rules and recommendations are brought to the attention of all persons entering the premises (or site);
- ensure that all relevant safety signs and rules are in languages understood by those persons;

There are also requirements for operators to take measures to prevent major accidents and limit their consequences They are required to develop and maintain a major accident prevention policy document. Attention is drawn to the Control of Major Accident Hazards Regulations 1999 [10], as amended (see Table A.1).

NOTE 2 The Health and Safety Executive provides information in a number of foreign languages.

- ensure that precise instructions are issued setting out the procedures for handling and testing equipment safely; and
- monitor the arrangements to ensure that these procedures are effectively carried out.

NOTE 3 Where procedures or processes that are the responsibility of the person in charge of the premises (or site) or of any contractor could endanger persons not in their employment, there is a legal obligation on the site management to provide information and instruction to all personnel about the safety procedures to be adopted.

Before commencement of work, the person in charge of the premises (or site) or employer should inform all instrument personnel of the potential hazards on site and the action to be taken in an emergency.

Management should ensure that all personnel are fully aware of their responsibility for the safety of installations under their control and for ensuring that their own work is carried out safely.

Instrument supervisors should be fully conversant with the safety requirements and recommendations, and should ensure that instrument personnel under their control have been made familiar with the site safety practices.

It is important that all instrument personnel are aware of the site arrangements for emergency services, including the type and location of available first aid equipment, the method of summoning medical assistance, the fire service and other emergency services, and that they also know the location of all the personnel assembly points in the event of a site emergency.

4.3 Permit-to-work

NOTE 1 Attention is drawn to HSE publication HSG250 [12].

NOTE 2 "Installation" in this context includes work on all plant and equipment within the area covered by the permit-to-work system, i.e. instrumentation, electrical switchgear, pressure testing, radiography, etc.

A permit-to-work may form part of the site procedures that enable an operating department to authorize certain specified engineering work to proceed on the installation. It should contain instructions on the nature of the work, the whereabouts and the part of the installation to which it applies, the protective equipment to be provided, and to be used or worn, the precautions to be taken, the precautions already taken, the period for which it is valid, the name of the person and organization to whom it is issued and the name of the person authorized to issue it. It should also include details of any additional permits deemed to be necessary for the safe execution of the work.

Paper copies of a permit-to-work should be clearly displayed at or near the work site and in the central or main control room.

If electronic permits can be used, they should have a suitable system in place to prevent unauthorized issue or acceptance, should not be able to be issued remotely without a site visit, should have a system in place to prevent permits already issued from being altered without the alterations being communicated to all concerned, and should have a suitable back-up in the event of a software failure or power outage.

A copy of the permit should be kept with the issuing authority, or with the area authority if that person is not located at the site or control room.

Operators should be adequately trained to assess the specific job and should not rely on cutting and pasting from other permits.

Instrument personnel working under a permit-to-work system should stop work if any unsafe conditions are found, and should inform the issuing and performing authorities immediately.

4.4 Work equipment

4.4.1 General

*COMMENTARY ON **4.4.1***
*Employers and the self-employed have a legal obligation, under the Provision and Use of Work Equipment Regulations 1998 (PUWER) [13], as amended (see Table A.1), to ensure that all equipment in their workplace is safe. The Regulations apply to all work equipment used, installed, commissioned, repaired, maintained, decommissioned or removed by instrument personnel, including work equipment used by personnel working from home. Guidance is given in **A.1.3**.*

NOTE 1 Attention of all personnel is drawn to HSE publications L22 [14] and INDG271 [15]. L22 is approved for use in Northern Ireland.

NOTE 2 HSE publications L22 [14] states that compliance with relevant European directives can be established by checking that the equipment bears the CE marking and asking for a copy of the Declaration of Conformity (DoC). Regulations do not always require the CE marking to be on the equipment, e.g. on small items. Neither does it always require the EC Declaration of Conformity to accompany equipment or to be in English.

NOTE 3 Equipment placed on the market before the mandatory dates for CE marking can still be installed and/or used, provided that it meets the requirements of the relevant regulations and is safe in accordance with the requirements of PUWER. Equipment that was put into use before the mandatory date for CE marking can continue to be used, maintained and repaired provided that it is safe in accordance with the requirements of PUWER. The mandatory date for CE marking varies according to the type of equipment in question.

NOTE 4 The onus for deciding which directives apply to (work) equipment is placed solely on the product manufacturer. Some regulations allow the CE marking to be on the packaging, delivery documentation or guarantee, or in the instructions for use. There are no specific requirements for the media on which the instructions for safe installation and use are to be provided.

A system to verify that the work equipment conforms to all relevant legislation should be established and documented.

Personal work equipment and employer provided work equipment used in the workplace should be registered with the employer and there should be periodic checks to ensure it is safe for the location, environment and application.

All markings and labelling, pertinent to equipment compliance or legislation should be recorded for future reference. Particular care should be taken to record markings on packaging before it is removed and disposed of.

All instructions for safe installation and use and their media/storage location should be recorded and all such instructions should be readily accessible to the intended user.

4.4.2 Instructions

NOTE UK regulations generally require instructions for the safe installation and use of (work) equipment to be in English.

Instrument supervisors should ensure that they and all personnel under their supervision are able to read the instructions and know the meaning of any warning pictograms before commencing work.

Instrument personnel should not use or install work equipment without having, and understanding, the manufacturer’s instructions for safe installation and/or use.

Before installation, it should be confirmed that the manufacturer's instructions essential for safe installation and use are available in paper format.

4.4.3 Use of tools

Acceptable standards for welding, brazing, the use of hand tools and portable machinery should be specified by the responsible engineer. It is essential that the practices adopted comply with the site requirements.

Installation personnel are responsible for the care, regular examination and arranging replacement (when necessary) of tools and equipment.

In areas where there might be a risk of fire or the presence of flammable material, installations should be carried out using only approved non-sparking tools used in accordance with permit-to-work procedures (see **4.3**).

Unattended tools should be left in a safe condition.

4.4.4 Electrical safety

*COMMENTARY ON **4.4.4***
*The Electrical Equipment (Safety) Regulations 1994 [16] apply to electrical equipment placed on the market that is designed or adapted for use between certain voltage limits, and cover all risks, electrical and mechanical, to the safety of persons, domestic animals and property. Guidance is given in **A.1.4**.*

Electrical equipment should conform to the relevant product standard. Examples include the following.

- Process instrumentation, test and measuring instruments and laboratory instruments should conform to BS EN 61010.
- Information technology equipment should conform to BS EN 60950.
- Electrical, thermal and energy safety of adjustable speed electrical power drive systems should conform to BS EN 61800-5-1.
- Programmable controllers should conform to BS EN 61131-2.

Where equipment is to be used in relation to functional safety in a safety-related system, the requirements of BS EN 61508 and BS EN 61511 should be followed where appropriate, and instrument personnel should be competent to install and commission the equipment.

4.4.5 Safety of machinery

*COMMENTARY ON **4.4.5***
*Machinery is subject to the Supply of Machinery (Safety) Regulations 1992 [17], as amended (see Table A.1). Guidance is given in **A.1.5**.*

Machinery supplied prior to the introduction of the Supply of Machinery (Safety) Regulations 1992 [17] should be used in accordance with the guidance given in PD 5304, which lists standards that can be used for demonstration of compliance with the Regulations.

Electrical equipment of machines should conform to BS EN 60204-1 in respect of general aspects of electrical safety. BS EN 60204-1 applies to electrical, electronic and programmable electronic equipment and systems of machines not portable by hand while working, including a group of machines working together in a coordinated manner.

Where machinery is to be used in relation to functional safety in a safety-related electrical, electronic or programmable electronic control system, the requirements of BS EN 62061 should be followed where appropriate, and instrument personnel should be competent to install and commission the equipment.

NOTE Although concerned with machinery safety, BS EN 614-1 provides useful guidance on ergonomic design of all work systems, including instrument systems, throughout their life cycle.

The installation design should take account of the ergonomic principles given in BS EN 614-1 for the safety of machinery throughout its life cycle.

4.4.6 Safety of pressure equipment

*COMMENTARY ON **4.4.6***
*This subclause only addresses equipment covered by the Pressure Equipment Regulations 1999 [18], as amended (see Table A.1). The Regulations do not apply to the assembly of pressure equipment on site(s) under the responsibility of the user, as in the case of industrial installations, or to pipelines outside an industrial installation: see **4.13** and **4.16**. Guidance is given in **A.1.6**.*

Pressure equipment conforming to the Pressure Equipment Regulations 1999 (as amended) is not subject to further pressure regulations during installation on site. However, ongoing use is subject to other regulations and in-service inspection.

Instrument personnel should ensure that the appropriate documentation for the instruments used on the pressure equipment is available before the equipment is put into use.

This documentation should be included in the documentation for the safe installation and use of the pressure equipment/assembly. It should include information showing conformity of pressure accessories, safety accessories and instruments that have been used in the equipment/assembly but have not been placed on the market as pressure or safety accessories. Where such accessories/instruments have not been placed on the market as pressure or safety accessories, the information provided should include the material requirements for pressure-bearing faces, including for flanges and thermowells, and the material manufacturer's certificate.

4.4.7 Hazardous area equipment

*COMMENTARY ON **4.4.7***
*Hazardous area equipment includes electrical and mechanical equipment, protective systems, safety devices, components and their combinations, which, separately or jointly, are intended for the generation, transfer, storage, measurement, control and conversion of energy and/or the processing of material and which are capable of causing an explosion in a potentially explosive atmosphere through their own sources of ignition. All such equipment is subject to the Equipment and Protective Systems Intended for Use in Potentially Explosive Atmospheres Regulations 1996 (ATEX Regulations) [19], as amended (see Table A.1). Guidance is given in **A.1.7**.*

Instrument personnel should not work on hazardous area equipment, inside or outside the hazardous area, unless they are competent to do so and, where relevant, are authorized under a permit-to-work system (see **4.3**).

4.4.8 Radio equipment and telecommunications terminal equipment (RTTE)

*COMMENTARY ON **4.4.8***
*RTTE is subject to the Radio Equipment and Telecommunications Terminal Equipment Regulations 2000 [20], as amended (see Table A.1). Guidance is given in **A.1.8**. Attention is also drawn to the Electromagnetic Compatibility Regulations 2006 (EMC Regulations) [21].*

The RTTE Regulations are intended to ensure the protection of the health and safety of the user and any other person, including the objectives with respect to safety requirements contained in Council Directive 73/23/EEC [2006/95/EC] [22, 23] but as if there were no voltage limit.

NOTE RTTE can be stand-alone or incorporated into IT equipment or process equipment and instrumentation.

Before radio equipment is installed, the user instructions should be checked to ensure that the equipment is suitable for connection to the public telecommunications network or to be used in the specific radio environment.

4.5 Personal protective equipment

*COMMENTARY ON **4.5***
Personal protective equipment (PPE) is defined as all equipment designed to be worn or held to protect against one or more risks to health and safety at work. Included are hard hats, safety footwear, life-jackets, eye and hearing protection, high visibility clothing and adverse weather (sufficient to cause a risk to health and safety) clothing, but not ordinary working clothes and uniforms, PPE for road transport or portable devices for detecting or signalling risks and nuisances. Also included is PPE intended for use in potentially explosive atmospheres, which has to be designed and manufactured so that it cannot be the source of an electric, electrostatic or impact-induced arc or spark likely to cause an explosive mixture to ignite.

Instrument personnel should wear PPE in accordance with site safety instructions. They should ensure that it is suitable for their use and not faulty before commencing work. If it is damaged while they are working, such that it no longer provides the intended protection, they should withdraw from the hazardous work area before reporting it to their employer.

PPE procured before the current Regulations can still be used, but employers should only allow such PPE to be used if they have retained evidence pertaining to its procurement.

Employees are required by the Personal Protective Equipment at Work Regulations 1992 [24], as amended (see Table A.1), to make full and proper use of PPE provided to them by their employer, to report any defective PPE to their employer and to return PPE to its storage space after use. Guidance is given in ***A.1.9****.*

4.6 Lifting and handling operations

4.6.1 Manual handling

COMMENTARY ON ***4.6.1***
Manual handling is subject to the Manual Handling Operations Regulations 1992 [25], as amended (see Table A.1). Guidance is given in ***A.1.10*** *and in HSE publication L23 [26].*

NOTE 1 Equipment and instruments conforming to BS EN 61010-1 will be fitted with lifting and carrying handles if weighing 18 kg or more, or be supplied with lifting and carrying instructions. The IET Code of practice for in-service inspection and testing of electrical equipment [27] suggests that equipment above 18 kg without lifting handles is classified as fixed equipment.

NOTE 2 There are no specific limits for the mass of a single-person lift. Guidelines on the Regulations recommend 25 kg for men and 16 kg for women.

Management personnel should ensure that the person(s) performing the lifting operation have been instructed in lifting techniques. Managers and supervisors should assess the risks for any equipment weighing 5 kg or more for men and 3 kg or more for women.

Instrument personnel performing lifting operations should only do so if they know the mass of the equipment, have taken into account their own physical capabilities, have been instructed in suitable lifting techniques, and, where appropriate, have the equipment manufacturer's instructions.

4.6.2 Lifting equipment

COMMENTARY ON ***4.6.2***
Lifting equipment is subject to the Lifting Operations and Lifting Equipment Regulations 1998 [28], as amended (see Table A.1). Guidance is given in ***A.1.11*** *and in HSE publication L113 [29].*

Instrument personnel should only participate in lifting operations under the supervision of a competent person, and should ensure that equipment is lifted in accordance with the manufacturer's instructions.

NOTE Where equipment is fitted with eyebolts, or where eyebolts can be fitted, there is a legal requirement for a manufacturer's or supplier's certificate of test to be made available.

Before eyebolts are fitted, the installer should ensure that the manufacturer's test certificate is available (see Note). Particular care should be taken to ensure that eyebolts are not overtightened or screwed into holes with a different thread form. Eyebolts should conform to BS 4278.

4.7 Working at height

*COMMENTARY ON **4.7***
*Working at height is subject to the Work at Height Regulations 2005 [30] and related legislation (see Table A.1). Guidance is given in **A.1.12** and in HSE publication INDG401 [31].*

NOTE 1 Where work at height is required, all employers, self-employed and persons controlling work at height of others are required to ensure that the work is properly planned and supervised, those working at height are competent, work equipment is selected and used that is appropriate to the work, risks from fragile surfaces are controlled and equipment for work at height is properly inspected and maintained.

Work at height should be avoided wherever possible.

Instrument personnel should only work at height if they have been trained and are competent to do so. Before working at height, personnel should ensure that any equipment to be used has been inspected and is safe to use.

Ladders should only be used where work at height is for a short period of time.

NOTE 2 Under the provisions of the Work at Height Regulations 2005 [30], personnel are not allowed to use equipment for work at height unless they have confirmed that it has been inspected. They are required to report any defect or activity relating to work at height that they know is likely to endanger the safety of them or others. They are also required to use the equipment in accordance with the instructions provided by their employer.

4.8 Safe access and egress

*COMMENTARY ON **4.8***
*Employers have a legal duty under the Workplace (Health, Safety and Welfare) Regulations 1992 [3], as amended (see Table A.1), to ensure suitable and sufficient access to and egress from workplaces and health/welfare facilities and, so far as is reasonable, to keep them free of obstructions that could cause a risk to health or safety. Safe access and egress are required to be provided for all persons likely to be in the workplace or health/welfare facilities, including persons with disabilities. Guidance is given in **A.1.13**.*

Instrument personnel should take care not to block access/egress routes when installing equipment and cables. Floor sections removed to give access to underfloor cable rooms should be surrounded by protective barriers to prevent falls.

Where obstructions are unavoidable, suitable instructions should be given to personnel, and clearly visible warning notices should be placed at or near the obstruction (see also **4.9**).

For work at height, additional precautions should be taken (see **4.7**).

4.9 Safety signs and signals

*COMMENTARY ON **4.9***
*Where the risk assessment made under the Management of Health and Safety at Work Regulations 1999 [2] (see **4.1**) indicates risks that cannot be avoided or adequately controlled in other ways, employers have a duty under the Health and Safety (Safety Signs and Signals) Regulations 1996 [32] to provide or use safety signs and signals, including fire safety signs. Management personnel also have a duty to ensure that employees receive adequate training in the meaning of safety signs and signals and the measures to be taken in connection with them. Guidance is given in **A.1.14**.*

Where verbal signals are used, either direct, by human voice, or indirect, by broadcast, management personnel have to ensure that the persons involved have a sufficiently good knowledge of the language used and that the verbal skills of hearers is sufficient to ensure reliable communication. Acoustic evacuation signals have to be continuous.

NOTE 1 Attention is drawn to HSE publications INGD184 [33] and L64 [34].

Fire safety signs should conform to BS 5499-1. Fire alarms should conform to BS 5839-1.

NOTE 2 Rotary or hand bells are also acceptable types of alarm.

Instrument personnel should not work in any area where there is a safety sign they do not know the meaning of, and should adhere to site safety instructions when working in an area covered by a safety sign.

4.10 Materials, dust and escaping fumes, gases and process fluids giving rise to fire, asphyxiation, toxic or explosion hazard

*COMMENTARY ON **4.10***
A potentially explosive atmosphere is an atmosphere that could become explosive under local and operational conditions and is a mixture with air, under atmospheric conditions, of flammable substances in the form of gases, vapours, mists or dusts in which, after ignition has occurred, combustion spreads to the entire unburned mixture.

Personnel should not work in or enter places where there are dangerous substances or explosive hazards identified by warning signs or in site safety instructions unless they have been suitably trained and instructed. They should adhere to the site safety instructions and work control procedures, and should report any defect in them to their employer.

Care should be taken by all personnel to avoid the escape of hazardous substances and preparations from the plant. Particular care should be taken where such escapes are not detectable by smell or where the sensory nerves in the nose can be desensitized by gradually increasing concentrations.

Dangerous substances and preparation are those that:

- *can cause fires and explosions or other energetic events such as runaway exothermic reactions or decompositions of unstable substances;*
- *can result in burns, blast injuries or asphyxiation;*
- *are a material, biological agent or dust (above certain concentrations) with the potential to cause harm to the health of a person.*

*Such atmospheres and substances are subject to the Dangerous Substances and Explosive Atmospheres Regulations 2002 (DSEAR) [35]. Guidance is given in **A.1.15**.*

*NOTE 1 See also **4.12**, **4.15** and Clause **5**.*

All personnel entering workplaces where there are dangerous substances should be made aware of the fire risks created by enriched oxygen atmospheres and oxidizing agents, including the likelihood of an increase in the flammability of clothing and the possibility that the hazard will persist for a time.

All personnel should be informed of the site safety emergency evacuation procedures, including the location of fire alarms and the method of initiating them, the operation of fire-fighting equipment, the position of escape routes and the reporting arrangements.

4.11 Physical agents

4.11.1 Mechanical vibration

*COMMENTARY ON **4.11.1***
*Attention is drawn to the Control of Vibration at Work Regulations 2005 [36]. Guidance is given in **A.1.16**.*

NOTE There is hand-arm vibration arising from the use of power tools, which is most likely to affect instrument personnel, if at all, and whole body vibration, which will affect people travelling in vehicles, particularly over rough terrain, such as in mines and quarries and on construction sites.

Management should ensure that site safety instructions include requirements to protect against risks arising from exposure to mechanical vibration, such that regulatory exposure limits are not exceeded, and to identify when action value limits are exceeded, necessitating implementation of exposure reduction measures.

Management should ensure that all persons likely to be exposed to mechanical vibration in the workplace are provided with adequate information and training.

Instrument personnel should be aware of the risks from mechanical vibration and should comply with site safety rules for protection of their health.

4.11.2 Noise

*COMMENTARY ON **4.11.2***
*Attention is drawn to the Control of Noise at Work Regulations 2005 [37]. Guidance is given in **A.1.17**.*

Noise can be a significant health risk at work.

Management should ensure that site safety instructions include requirements to monitor and control noise.

Management should have procedures in place to ensure that ear protectors are used when needed, and to inform and train personnel before they work in noisy areas.

As far as reasonably practicable, control of noise should take place at the design stage, through selection of equipment and layout of the plant and control room. Installation of instruments in noisy locations should be avoided if they are intended to be monitored frequently.

Instrument supervisors should ensure that instrument personnel only install instruments in noisy areas under strict control. Ideally, noisy plant and equipment should be switched off for installation of instruments.

4.11.3 Electromagnetic fields

*COMMENTARY ON **4.11.3***
*There is at present no UK legislation specific to electromagnetic fields. Control is exercised through the general duties in the Health and Safety at Work etc. Act 1974 [1], the Management of Health and Safety at Work Regulations 1999 [2] (see **A.1**), and by reference to ICNIRP guidelines. A European Directive, 2004/40/EC [38], was to be implemented in national regulations by 30 April 2008, but has been deferred until 30 April 2012.*

NOTE Attention is drawn to NRPB Document Volume 15, No.2 [39]. The NRPB is now incorporated in the Health Protection Agency Radiation Protection Division (HPA RPD).

Management should ensure that site safety instructions contain procedures for the measurement of electromagnetic fields to ensure that guidance limits for the protection of workers from their short-term affects are not exceeded.

Instrument personnel are likely to work with or near equipment that has been identified as of particular concern. This can include electricity generating equipment, resistance welders, magnetic tape erasers, crack detection equipment, induction dielectric heater, plasma etchers, RF sputtering units, RFID systems, electronic surveillance equipment and broadcast/telecommunications equipment. Controls should be in place for working with or near such equipment.

4.11.4 Optical radiation

*COMMENTARY ON **4.11.4***
*At present there are no specific legislative requirements for protection from optical radiation. This is covered by the general duties to assess risks in the Health and Safety at Work etc. Act 1974 [1] and the Management of Health and Safety at Work Regulations 1999 [2] (see **A.1.1**).*

4.11.4.1 General

Management personnel should ensure that procedures are in place to control the exposure of workers to all types of optical radiation (artificial and natural). Optical radiation covers the ultraviolet, visible and infrared wavelengths, i.e. between 100 nm and 1 nm.

4.11.4.2 Artificial optical radiation

NOTE 1 New regulations will be put in place for artificial optical radiation, to become effective from 27 April 2010. These are expected to be based on ICNIRP guidelines and to give exposure limit values that are designed to prevent adverse health effects, mainly to the skin and eyes, which are most at risk from optical radiation. They are expected to place duties on employers to assess and control exposure, reduce risk, provide information and training and make provisions on health surveillance for laser and broadband (non-coherent) sources of artificial optical radiation.

For protection from exposure to artificial optical radiation, the ICNIRP guidelines should be followed. Artificial optical radiation can be coherent (lasers) or non-coherent.

Where class 3A, class 3B or class 4 lasers are in use, a permit-to-work system should be employed (see Note 2 and **4.3**).

NOTE 2 Where such lasers are in use, there is a legal requirement to appoint a laser safety officer.

Laser equipment should conform to the classifications specified in BS EN 60825 and should be used in accordance with BS EN 60825 and PD IEC/TR 60825-14.

Free space optical communication systems used for the transmission of information should conform to BS EN 60825-12.

Optical fibre communication systems should conform to BS EN 60825-2.

Instrument personnel should be aware of the risks from optical radiation and should not commence work unless they have the appropriate documentation for the equipment, including the manufacturer's instructions for use. The documentation for laser-related equipment should as a minimum conform to the requirements specified in BS EN ISO 11252.

Instrument personnel should only work on laser equipment if they wear suitable eye protection. Laser eye protectors for adjustment work on lasers and laser systems should conform to BS EN 207.

4.11.4.3 Natural optical radiation

NOTE Attention is drawn to HSE publications INDG337 [40] and INDG147 [41].

Instrument personnel working outside should take particular care to ensure they have adequate protection against ultraviolet radiation, e.g. by wearing appropriate personal protective equipment (see **4.5**).

4.12 Work in confined spaces

*COMMENTARY ON **4.12***
*Where there is a risk of death or serious injury from hazardous substances or dangerous conditions (e.g. lack of oxygen) the Confined Spaces Regulations 1997 [42] apply. Examples of confined spaces are storage tanks, silos, reaction vessels, enclosed drains, sewers; open-topped chambers, vats, combustion chambers in furnaces etc.; ductwork and unventilated or poorly ventilated rooms. Guidance is given in **A.1.18**.*

NOTE Attention is drawn to HSE publications L101 [43] and INDG258 [44].

Employers are required to avoid the need for anyone to work in confined spaces wherever practicable. However, instrument personnel are likely to work in confined places, such as plant, instrument cubicles, ducts, unvented or poorly vented rooms, behind wall panels and in areas where there are gas-flooding fire extinguishing systems. Site safety instructions should therefore include requirements for working in confined spaces where there are risks from oxygen deficiency, poisonous gases fumes or vapours, dangerous substances, high dust concentrations or hot conditions. A permit-to-work system should be employed where there are such risks (see **4.3**).

It should be ensured that there is a sufficient supply of fresh air before any person enters a confined space, e.g. by securing doors in the open position or removing them completely, removing duct coverings, or removing panelling. Forced ventilation should be installed where necessary.

Where there is a risk from toxic or flammable vapours, the atmosphere in the confined space should be tested immediately before entry into it, using a correctly calibrated gas detector. Where there is likely to be a change in the atmosphere, continuous monitoring should be employed.

Non-sparking tools and specially protected lighting are essential where flammable or potentially explosive atmospheres are likely.

Work involving welding, brazing or the use of solvents and glues should be avoided in confined spaces. Where this is not possible, work should be closely supervised, time restricted, and a permit-to-work system employed.

In all confined spaces where the air quality cannot be guaranteed, breathing apparatus should be worn.

No person should enter or work in a confined space unless there is a person outside within sight and sound. Persons working in confined spaces and those outside monitoring the work should be adequately instructed in all relevant emergency procedures.

4.13 Pressure equipment

*COMMENTARY ON **4.13***
*Attention is drawn to the Pressure Systems Safety Regulations 2000 [45]. Guidance is given in **A.1.19**. See also the Pressure Equipment Regulations 1999 [18], as amended (see Table A.1), in **4.6**, **4.4.6** and **A.1.6**.*

NOTE 1 Attention is drawn to HSE publication L122 [46].

NOTE 2 Pressure equipment and assemblies meeting the requirements of the Pressure Equipment Regulations 1999 [18], as amended (see Table A.1), can be installed without any additional assessment.

Instrument personnel should only work on pressure equipment under the supervision of a competent person. A permit-to-work system should be employed (see **4.3**).

Measuring and control instruments and systems and protective devices should only be installed if they are fit for purpose with respect to safety. They should be installed in accordance with the manufacturer's instructions for safe installation and use.

Materials for pressure-bearing faces of instrumentation should be suitable for the intended use. It is recommended that a log be kept of the material manufacturer's certificates, which should be obtained from the instrument/pressure equipment, system or assembly manufacturers.

Pressure equipment should be provided with suitable measuring or indicating devices to give clear indications of relevant critical conditions, such as temperatures, pressures and liquid levels, and their display should be clearly visible. Pressure-relieving devices should have an adequate discharge capacity in order to limit pressure to within safe operating limits and, where appropriate, should be able to deal with the dynamic flow characteristics of those fluids which result in two phase flow conditions. Gauge glasses, e.g. on tubular water level gauges, should be effectively protected to prevent injury from the glass breaking and the contents being ejected.

Where high and/or low fluid levels could lead to unsafe conditions, such as in water boilers, suitable fluid level indicators and alarms should be fitted directly to the plant equipment.

Where the safety of pressure equipment and systems is controlled by safety instrumented systems, these systems should conform to BS EN 61511.

Where installation work necessitates breaking into process or impulse lines which are, or have been, in operation, care should be taken to reduce any risks that could arise from the escape of dangerous substances or fluids under pressure, e.g. compressed air, natural and other gases, steam, oxygen, water and chemicals. Such lines should be fully isolated from the remainder of the system and made safe for work by removing the contents by draining, venting and purging, where necessary. Isolation should be achieved by the use of isolating valves, manually secured in the closed position, while valves used for draining and venting should be secured in the open position. Control valves should not be used for these purposes and it should be noted that single valve isolation cannot be relied upon. In such situations, two isolating valves are normally provided for this purpose, but where this is not the case it might be necessary to fit an isolation spade in the line. The latter is particularly recommended if the isolation is applied over an extended period of time.

Hydraulic pressure testing of impulse lines should be done with liquids compatible with the process fluid and should not contaminate the interior of the impulse lines. Testing should only be carried out after disconnection of all instruments that might be damaged by the test pressure.

4.14 Work on or with electrical systems and equipment

*COMMENTARY ON **4.14***
*Electrical installations in all workplaces are subject to the Electricity at Work Regulations 1989 [47]. The Regulations cover all electrical systems and equipment used, intended to be used or installed for use, to generate, provide, transmit, transform, rectify, convert, conduct, distribute, control, store, measure or use electrical energy. Guidance is given in **A.1.20** and in HSE Guidance Note GS38 [48].*

*All work equipment, including fixed, portable or transportable instruments and equipment connected to a source of electrical energy, is also covered by the Provision and Use of Work Equipment Regulations 1998 [13], as amended (see **4.4, A.1.3** and Table A.1).*

Instrument personnel should only work on electrical systems or connect instruments and equipment to the site electrical installation if they are competent to do so or are adequately supervised by a competent person.

No person should work on live electrical systems unless it is impracticable to do otherwise. Work on live electrical systems requires special tools, and only those tools should be used. A permit-to-work system should be employed for live working on electrical systems (see **4.3**).

NOTE In hazardous areas, live working is not permitted except on intrinsically safe equipment.

Wherever possible all equipment should be isolated from its electrical supply before any work commences. Procedures should be in place to ensure that the supply cannot be reconnected whilst work is in progress. Appropriate and known working voltage detectors should be used to confirm that the voltage has been disconnected before work commences. Isolation procedures should conform to the guidance in BS 6423.

4.15 Potentially explosive atmospheres

*COMMENTARY ON **4.15***
*The Dangerous Substances and Explosive Atmospheres Regulations 2002 (DSEAR) [35] require workplaces to be assessed for areas where there are potentially explosive atmospheres. Areas where explosive atmospheres might occur have to be classified into zones and have to be protected from sources of ignition by suitable equipment and protective systems. Where necessary, hazardous areas have to be marked with the "EX" sign at the point of entry. Guidance is given in **A.1.15** and in HSE publications L134 [49], L135 [50], L136 [51] and L138 [52].*

*NOTE See also **4.4.7** and **4.10**.*

Explosion prevention and detection measures should be implemented in accordance with BS EN 1127-1. Equipment for use in hazardous areas should conform to BS EN 60079-10.

Instrument personnel should be made aware of the hazardous areas on the site before starting work and should not work in them unless they are competent to do so, have all necessary PPE (see **4.5**) and have been instructed in the emergency warning and evacuation procedures.

4.16 Ionizing radiation and radioactive substances

4.16.1 General

NOTE Instrument personnel working in radioactive controlled or supervised areas are required to be classified.

Site safety instructions should include requirements for working with or near apparatus generating hazardous levels of ionizing radiation or containing hazardous levels of radioactive substances, and, where appropriate, their safe storage. Instrument personnel working in radioactive controlled or supervised areas should ensure that they use the supplied PPE (see **4.5**), particularly dose rate monitors, and that they maintain records and log books accurately.

All persons involved should be instructed on the hazards and the handling of equipment and instruments generating hazardous levels of ionizing radiation or containing radioactive substances.

No work should commence on or near equipment generating hazardous levels of ionizing radiation or containing radioactive substances without following the manufacturer's detailed instructions for safe handling, installation and use. It is recommended that control procedures be in place for storage of manufacturers' instructions. Particular care should be taken to control the storage of instructions provided in electronic format.

4.16.2 Ionizing radiations

*COMMENTARY ON **4.16.2***
Attention is drawn to the Ionising Radiations Regulations 1999 [53].

Equipment generating ionizing radiations that might be encountered by instrument personnel that require authorization/generic authorization by the Regulator for use include:

- *X-ray sets intended for industrial radiography, e.g. for non-destructive testing of welds and joints;*
- *X-ray sets for processing of products that include some physical, chemical or biological change in the material being processed;*
- *accelerometers (other than electron microscopes) emitting ionizing radiation with an energy higher than 1 MeV, including those used for industrial purposes and non-destructive testing.*

Where it is planned to use this equipment, employers are required to appoint a radiation protection supervisor (RPS).

NOTE X-ray gauging and detection systems in measurement processes do not require any authorization.

Personnel should only work on or near ionizing radiation equipment when under the control of the RPS.

4.16.3 Radioactive substances

*COMMENTARY ON **4.16.3***
Keeping and using radioactive materials and mobile radioactive apparatus, and accumulation and disposal of radioactive waste, has to be registered with the appropriate Regulator, with some exceptions. Radiation substances are not subject to registration if they do not exceed a specified quantity or concentration per unit mass, or where they are HSE type approved apparatus or constructed in the form of a sealed source and do not cause a dose rate of more than 1 μSvh^{-1} at a distance of 0.1 m from any accessible surface under normal operating conditions, and where conditions for disposal have been agreed by the Regulator. Registered radioactive material and apparatus are required to be protected against accidental damage or loss under the control of the supervisor. Instrument personnel are required to report to the supervisor any loss or damage to radioactive material or apparatus.

NOTE 1 This subclause does not cover license holders for nuclear installations.

NOTE 2 Where it is planned to use radioactive substances emitting ionizing radiation, employers are required to appoint a radiation protection supervisor (RPS).

Instrument personnel should adhere to the control procedures and should only work with or near radioactive substances emitting ionizing radiation when under the supervision of the RPS. Sealed source apparatus is the type most likely to be encountered by instrument personnel, who should not handle, use or install such apparatus without following the manufacturer's detailed instructions.

It is recommended that:

a) radioactive sources securely attached to machines or other fixed equipment are checked once a month and after maintenance or repair that could have affected the source;

b) portable radioactive sources are checked daily.

Records should be kept of all checks.

4.17 Working with display screens

*COMMENTARY ON **4.17***
Workstations involving display screen equipment are required to be ergonomically designed if regularly used. Particular care needs to be taken in control rooms for workstations that have multiple screens. Regular use of display screens is considered to be more than 1 h per day or 5 h per week.

*Attention is drawn to the Health and Safety (Display Screen Equipment) Regulations 1992 [54], as amended (see Table A.1). Guidance is given in **A.1.21**.*

The design, layout, dimensioning, environmental requirements and evaluation of control centres should be carried out in accordance with BS EN ISO 11064, which also gives principles for the arrangement of control suites and layout of control rooms. The ergonomic principles for work with display screens based on flat panels should follow the requirements specified in BS EN ISO 13406.

Work with display screens by instrument personnel is likely to be for long periods, especially during commissioning. Work should be planned to take breaks or change activity. It is recommended that breaks should be taken for 5 min to 10 min in every hour.

Personnel who consider they are having vision problems due to work with display screens should report it to their employer and request an eyesight test.

NOTE 1 This subclause does not cover office work with display screens.

NOTE 2 Employers are required to provide sight tests where problems arise as a result of working with display screens.

4.18 Work on construction sites

*COMMENTARY ON **4.18***
*The Construction (Design and Management) Regulations 2007 [55] apply to temporary and mobile construction sites. They concern occupational health, safety and welfare in construction, and place duties in relation to management arrangements and practical measures on a range of construction project participants, including clients, designers and contractors. They apply to all temporary and mobile construction sites, but give additional requirements where a project is notifiable, including the duty of the client to appoint a CDM coordinator and a principal contractor. Guidance is given in **A.1.22**.*

NOTE Attention is drawn to HSE publication L144 [56].

Where installation of instrumentation is on a construction site, instrumentation managers and supervisors should ensure that they are fully familiar with the health and safety plan of the principal contractor before any installation work commences. They should raise any concerns they have about the plan with the principal contractor and ensure that these are adequately addressed before any installation work commences.

Instrumentation managers and supervisors should ensure that all personnel under their control have been adequately instructed on the site health and safety plan and have the appropriate PPE (see **4.5**) before entering the site and starting work.

Instrument personnel working on a construction site should adhere to the safety rules, wear the supplied PPE, and report any risk to health and safety that they identify and any faulty PPE.

5 Instrumentation in hazardous areas

*COMMENTARY ON CLAUSE **5***
This clause covers the installation of electrical and non-electrical instrumentation in areas that are defined as being hazardous due to the presence of flammable gases, vapours, mist and/or dusts or of the likelihood of them occurring in both onshore and offshore installations.

*NOTE 1 The precautions necessary for personnel safety are given in **4.4.7**.*

NOTE 2 Requirements for electrical installations on mobile and fixed offshore units are given in BS IEC 61892-7.

NOTE 3 Terms and definitions for equipment and protective systems intended for use in potentially explosive atmospheres are given in BS EN 13237.

5.1 Classification of hazardous areas and selection of instrumentation

*NOTE 1 Attention is drawn to the legal requirement under DSEAR [35] to classify all areas where potentially explosive atmospheres can occur, and to install and use only suitable instrumentation. See **4.15** and **A.1.15**.*

Before starting work in an installation, the risk assessment identifying and classifying any hazardous areas should be available (see BS EN 60079-10 for classification of hazardous areas) and it should be confirmed that controls are in place to ensure compliance with regulatory requirements. The controls should prevent equipment being taken into a classified hazardous area if it is not correctly certified and/or marked for the zone and the nature of the hazard (simple apparatus does not have to be marked), unless:

a) there has been a specific risk assessment for the equipment included in the site risk assessment; or

NOTE 2 This option is not preferred and should only be considered where there is no suitable certified and/or marked equipment available. Close cooperation is needed between the manufacturer, installer and person responsible for the installation's risk assessment.

b) the area has been certified as free of an explosive atmosphere.

The use of steel tools might cause an unacceptable risk of ignition due to incendive sparking in Zones 1, 2, 21 and 22. However, tools should only be taken into a hazardous area by personnel having knowledge of the risk associated with incendive sparking.

Extremely small apparatus and Ex components might not be marked. Where this is the case, it should be confirmed that the manufacturer has provided documentation with the apparatus or component having the markings.

Portable, transportable and hand-held equipment should only be used in areas appropriate to the type of protection. Where there is a risk of such equipment being inadvertently taken into a hazardous area with a higher classification, the equipment should be suitable for the highest classification where it can be taken.

Some tools and equipment can become electrostatically charged. Precautions for avoiding electrostatic hazards in explosive atmospheres should be taken in accordance with PD CLC/TR 50404.

Appropriate clothing and footwear should be worn when in a hazardous area not certified as free of an explosive atmosphere (see also **4.5**).

Before installation begins in a classified hazardous area, it should be confirmed that the equipment manufacturer's declaration of conformity and instructions for the safe assembly, installation, commissioning, taking into service, operation, maintenance and decommissioning/dismantling are available.

All warnings on equipment should be noted and procedures put in place to ensure that they are adhered to, since they take precedence over any other instructions.

Surface applications at mines and quarries should be subject to the same risk assessment as used in other industries, and the same forms of protection should be used as for any other non-underground applications. For example, a gas-fired power generation plant installed on the surface of a mine would have a control system designed in the same manner as that of a non-mining application fired with landfill or natural gas.

NOTE 3 Mining and quarrying applications, particularly underground, are subject to statutory regulation and approval. Attention is drawn to mines and quarries legislation in respect of the installation of instrumentation and monitoring equipment. This requires all such equipment and installation to conform to BS EN 60079-1 specifically for group 1 gases.

5.2 Electrical apparatus

The selection, installation, testing and inspection of electrical apparatus in hazardous areas should be carried out in accordance with:

a) BS EN 60079-14 and BS EN 60079-17 for gases and vapours;

b) BS EN 61241-14 and BS EN 61241-17 for dust.

Electrical apparatus intended for use in hazardous areas should conform to the relevant standard, i.e. BS EN 60079 series for explosive gas atmospheres and BS EN 61241 series for explosive dust atmospheres and combustible dust layers.

1) Equipment suitable for use in Zone 0 is Ex ia and Ex MA and Zone 20 is Ex tD, Ex iaD and Ex maD. The use of dual protected equipment in accordance with BS EN 60079-26 is permitted in Zone 0.

2) Equipment suitable for use in Zone 1 is any equipment suitable for use in Zone 0 and Ex d, Ex p, Ex q, Ex o, Ex e, Ex ib and Ex mb, and in Zone 21 is any equipment suitable for use in Zone 20 and Ex tD, Ex PD, Ex ibD and Ex mbD.

3) Equipment suitable for use in Zone 2 is any equipment suitable for use in Zones 0 and 1 and Ex nA, Ex nL, Ex nR, Ex nC and Ex nP, and in Zone 22 is any equipment suitable for use in Zones 20 and 21 and Ex tD and Ex PD.

CAUTION. Where working in hazardous areas with installed equipment conforming to superseded standards and Regulations, care should be taken to avoid confusion with markings. Particular care should be taken if considering replacing this equipment with equipment conforming to the new standard, as it might not be compatible. Consultation with the manufacturer is recommended.

The use of electronic equipment should be controlled where there is a risk of RF emissions, intended or otherwise, affecting hazardous area equipment, either inside or outside the hazardous area, and structures in hazardous areas to the extent that the safety of the hazardous area can be compromised. Particular care should be taken to control the taking/use of personal portable electronic devices such as walkie talkies, PDAs, mobile phones, remote controls, watches, cameras and laptops/hand-held computers, into hazardous areas or near hazardous area apparatus, especially where, for safety reasons, cable screens are only terminated at one end, so that the screens can act as antennas, or near to structures in hazardous areas that can act as antennas.

*NOTE 1 Non-hazardous area aspects of electrical/electronic instrument safety are covered in the relevant product standard (see **4.4.4**).*

NOTE 2 The BS EN 50000 series (i.e. BS EN 50014 to BS EN 50021) is gradually being replaced by the BS EN 60079 series. The appropriate standards to use need to be confirmed before commencing work.

*NOTE 3 Equipment that was placed on the market before the mandatory date of the ATEX Regulations [19] can still be put into use provided that a risk assessment has been carried out and it is safe in accordance with the requirements of PUWER (see **4.4**).*

*NOTE 4 Attention is drawn to DSEAR [35] (see **A.1.15**), which generally requires that only electrical equipment having the European Epsilon-x mark (ATEX) can be installed and put into use in a hazardous area. Equipment with only other marks, such as IECEx (the IEC hazardous area certification scheme), cannot usually be installed and put into use in a hazardous area, even if it conforms to the same standard.*

NOTE 5 There is a form of protection Ex s, special equipment, for which there is no standard. The manufacturer and certification body have to ensure that the apparatus is safe for use in the intended hazardous area. If such equipment is to be used there should be close cooperation between the manufacturer, installer and person responsible for the installation's risk assessment.

NOTE 6 The requirements in the BS EN 61241 series will eventually be incorporated into the BS EN 60079 series.

NOTE 7 PD CLC/TR 50427 gives guidance on power thresholds of RF impinging on hazardous area structures, that can act as antennas, from outside the hazardous area.

5.3 Batteries, power packs and portable electrical equipment

5.3.1 General

Controls should be in place to prevent the inadvertent taking of batteries into hazardous areas, particularly spares for portable electric/electronic equipment, and to check that batteries in hazardous area apparatus are only replaced with batteries of the correct type, according to the apparatus manufacturer's instructions, and have been correctly fitted.

5.3.2 Battery replacement

Only batteries or power packs recommended by the manufacturer for the particular model of certified instrument or equipment should be used.

NOTE The fitting of a non-recommended battery or power pack to certified equipment will invalidate the equipment's certification.

All battery or power pack replacement should be undertaken in a non-hazardous area, and/or in accordance with an approved safe process.

5.4 Non-electrical equipment

*COMMENTARY ON **5.4***
Under the terms of the ATEX Regulations [19], non-electrical equipment placed on the market after the mandatory date can generally only be installed and used in hazardous areas if it has the European Epsilon-x mark.

Non-electrical equipment assessment requirements are as follows.

- *Category 3 equipment needs to be safe for use in normal operation. It can be self-assessed by the manufacturer, who is required to maintain a technical file.*
- *Category 2 equipment needs to be safe for use in normal operation and expected malfunction. It can be self-assessed by the manufacturer, but a technical file has to be lodged with a notified body.*
- *Category 1 equipment needs to be safe for use in normal operation, expected and rare malfunction. It has to be assessed by a notified body.*

The risk assessment should identify potential ignition sources.

Non-electrical equipment should conform to the relevant standard in the BS EN 13463 series of standards:

a) all non-electrical equipment should meet the general requirements specified in BS EN 13463-1;

b) equipment suitable for use in Zones 2 and 22 should meet the flow restriction (fr) requirements of BS EN 13463-2;

c) equipment suitable for use in Zones 1 and 21 should meet the requirements of:
   - BS EN 13463-3 for flameproof (d); or
   - BS EN 13463-5 for constructional safety (c); or
   - BS EN 13463-6 for control of ignition sources (b); or
   - BS EN 13463-7 for pressurization (p); or
   - BS EN 13463-8 for liquid immersion (k).

6 Documentation

Before design of the installation begins, the document management system and documentation requirements should be agreed with the site owner/operator and prime contractor.

The document management system should have an audit trail and should address format, media, accessibility, security and storage, and there should be a periodically validated, documented, systematic back-up and restore procedure, disaster recovery procedure and software and documentation traceability procedure, for business continuity management. It should meet the requirements of BS ISO 15489-1 and BS ISO/IEC 27001, which gives the requirements for information security management.

Electronic documentation management systems should meet the recommendations of BIP 3081 (BIP 0008 and BIP 0009).

NOTE 4 BIP 0008 is the actual code of practice and BIP 0009 is a workbook designed to enable a historical audit trail of compliance to BIP 0008.

NOTE 5 There are a number of proprietary systems currently in use in the process industries. Manufacturers, suppliers and installation designers might be contractually obliged to provide documentation in acceptable formats for one of these. A number of standards for electronic data exchange of product data and engineering information have been or are being developed that might be suitable for use in the process industries, but have not yet been widely taken up. Published standards include BS ISO 10303, ISO 15926, BS EN 61804 and BS EN 61987-1. Various standards are being developed, including IEC 62424.

NOTE 1 Guidance on BS ISO 15489-1 is given in PD ISO/TR 15489-2. BIP 0025 also gives guidance on the practical implementation of BS ISO 15489-1 and management guidance as to its value and to the performance management of it. BS 7799-3 gives guidance and support for the implementation of BS ISO/IEC 27001, and BS 7799-1 is a code of practice for information security management. BS 25999-2 addresses business continuity management.

NOTE 2 Documentation and records management is relevant to traceability, compliance, accountability, integrity and availability of information.

NOTE 3 Information security is an essential part of documentation management. The standards cover all aspects of security for documentation, such as personnel, building access, storage, storage access, protection against the environment, equipment used and utility supplies to and protecting it, access to the equipment, mobile computing and communications and operational procedures.

NOTE 4 BS ISO/IEC 20071 specifies the requirements for establishing, implementing, operating, monitoring, reviewing, maintaining and improving a documented information security management system, so requirements can change through a project.

7 Process sensors and measuring devices

*COMMENTARY ON CLAUSE **7***
This clause deals with devices commonly used in industry for the measurement of flow, pressure, temperature, level and some mechanical functions such as speed and vibration.

The detecting element or measuring device responds directly to the physical condition, and its location needs to be carefully selected so that the reading or output obtained is truly representative of the variable to be measured.

7.1 Flow

7.1.1 General

COMMENTARY ON ***7.1.1***
There are many types of flow measuring device which are each appropriate for a different range of applications. Many of these devices form part of the process pipework and therefore may be installed by mechanical rather than instrument personnel.

Flowmeters often have considerable commercial importance when the price paid for a quantity of product is calculated from flowmeter readings. These metering applications require high accuracy and repeatability.

Custody transfer and fiscal meter systems employ calibrated flowmeters and often use density, temperature or pressure measurements close to the flowmeter to allow corrections to standardized set of conditions to be made. These measurements should be made so that they are representative of the whole flow. Installation of devices for these correction measurements should be in accordance with **7.1.2** to **7.1.11** as appropriate.

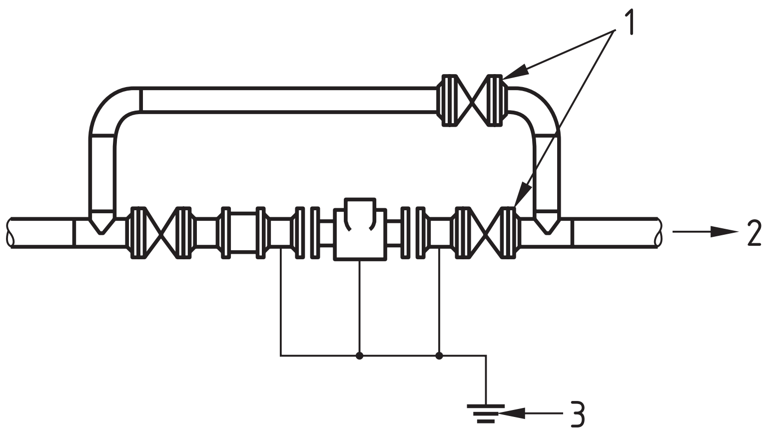
Where the flowmeter has been calibrated complete with adjacent pipe sections, the whole calibrated assembly sequence should be detailed unambiguously on the certificate. Where practicable, the entire assembly as calibrated should be delivered in one piece for installation. If the equipment needs disassembling to facilitate transport from the calibration facility, all sections of pipework, flow straightener(s) and meter, etc., should be clearly labelled such that their sequence and orientation can be replicated precisely at installation. It might also be advisable to document torque settings and tightening sequences. The level of disassembly should be minimized. All parts should be suitably protected from the environment and in a manner which protects them from any damage during transit. Failure either to deliver the parts in a controlled manner or to replicate precisely the assembly at installation might render the calibration certificate invalid.

It is essential that all flow measuring devices are installed precisely according to the design requirements and that no alteration be made without prior reference to the responsible engineer. This applies particularly to straight-pipe length requirements upstream and downstream of the device.

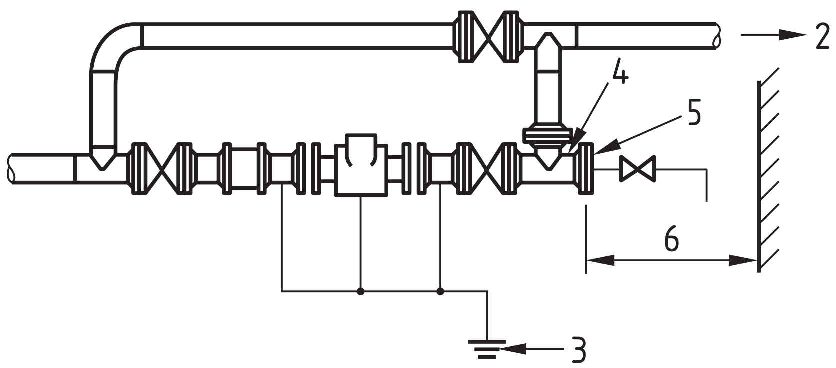
Instrument manufacturers' instructions should be retained and the specified installation procedure strictly followed in order to minimize the risk of measurement inaccuracies, instrument damage or warranty issues.

Where flow interruption for maintenance or for zero checking is not acceptable, bypass pipework may be incorporated. Examples of arrangements are shown in Figure 1. If a cleanout tee is required, the recommended arrangement is shown in Figure 1b).

Figure 1 **Typical in-line flowmeter installations**



a) Standard installation



b) Installation with a clean-out tee

Key

1 Bypass and isolating valves as specified
2 Flow
3 Piping and transducer earthed to manufacturer's instructions
4 Clean-out tee
5 Blank flange with drain valve
6 Access clearance

7.1.2 Differential pressure

7.1.2.1 Principle

Flow through a primary element causes a fall in static pressure and the differential pressure so created is a function of the flow rate. This differential is measured by a differential pressure instrument which may be calibrated in flow units, or the conversion to flow units may be performed on the instrument output signal elsewhere.

7.1.2.2 Installation arrangement

7.1.2.2.1 Primary element location

To obtain the best accuracy from a differential pressure flow measurement it is important that flow disturbances are eliminated before they reach the measuring point. Selection of a measurement location preceded by a sufficient length of straight piping will minimize such disturbances. The length of straight piping depends upon the source of disturbance, such as valves, bends, tees, concentric/eccentric reducers, or changes in section upstream of the device and on the type of primary element employed. Minimum straight lengths upstream and downstream to obtain the desired accuracy and repeatability of measurement are specified in BS EN ISO 5167-2, BS EN ISO 5167-3 and BS EN ISO 5167-4, and should be incorporated in the pipework design. Where it is not practicable to accommodate straight lengths, flow conditioners or straighteners should be used (see BS EN ISO 5167-1:2003, **7.2.2** and **7.4**).

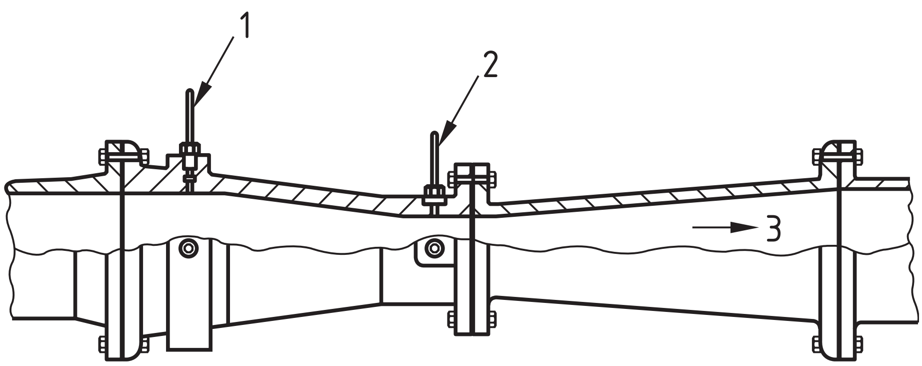
7.1.2.2.2 Primary element mounting

Certain primary elements, particularly nozzles or Dall inserts, are mounted within the process pipework. To facilitate installation and removal of these inserts they should normally be located at the inlet to a short flanged pipe spool.

7.1.2.2.3 Tapping point location

Tapping points may be integral with the primary element, be part of a carrier ring or be made on the pipe itself in accordance with the design specification and BS EN ISO 5167-2 (see Figure 2, Figure 3 and Figure 4).

Figure 2 **Typical tapping point location on a Venturi tube**



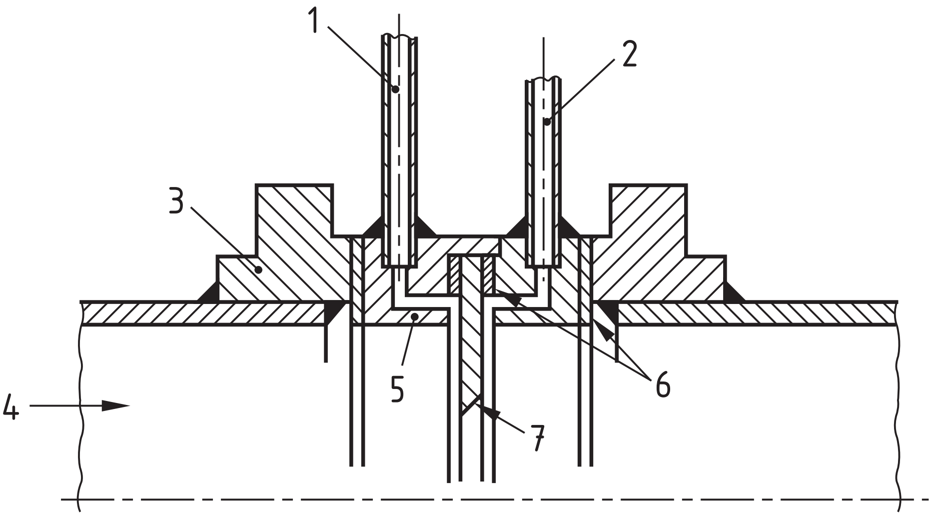
Key

1 High pressure connection

2 Low pressure connection

3 Flow

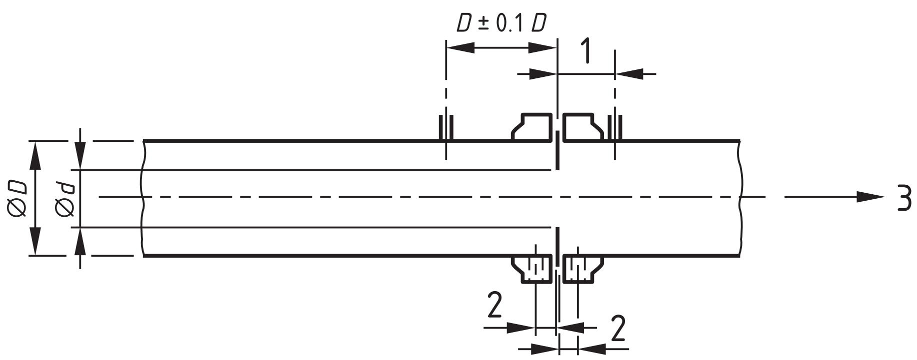
Figure 3 **Typical pipe tapping point location on an orifice plate carrier ring**



Key

1 High pressure connection
2 Low pressure connection
3 Pipe flange
4 Direction of flow
5 Carrier ring
6 Gasket or joint rings should not protrude into flow or obstruct tapping slot
7 Orifice plate

Figure 4 **Typical tapping point locations for flange-mounted orifice plate**



NOTE β is the diameter ratio, $\beta = \frac{d}{D}$

Key

1 Pipe tappings:
$0.5D \pm 0.02D$ for $\beta \leqslant 0.6$
$0.5D \pm 0.01D$ for $\beta > 0.6$

2 Flange tappings:

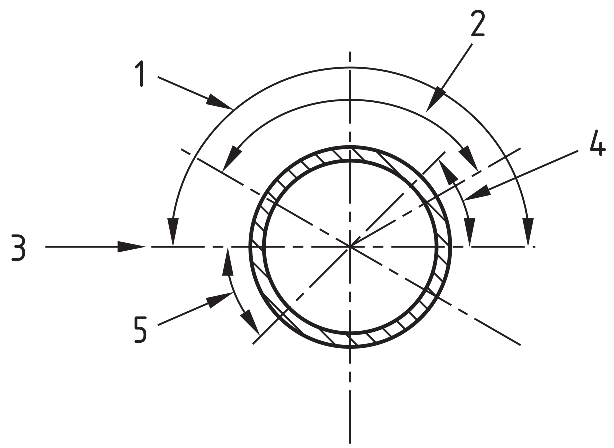
(25.4 ± 0.5) mm	for $\beta > 0.6$	and	58 mm < D < 150 mm
(25.4 ± 1.0) mm	for $\beta \leqslant 0.6$		
or	for $\beta > 0.6$	but	50 mm ⩽ D ⩽ 58 mm
or	for $\beta > 0.6$	but	150 mm ⩽ D ⩽ 760 mm

3 Direction of flow

7.1.2.2.4 Tapping points on horizontal or sloping pipes

The radial location of the tapping points on horizontal or sloping pipe sections should take into account the nature of the process fluid as shown in Figure 5. Other orientations are permissible but might require special arrangements for venting and draining.

Figure 5 **Typical radial location for tappings on a horizontal or sloping pipe**



Key

1 Dry gas
2 Wet gas
3 Steam or vapour
4 Liquid with suspended solids
5 Clean liquid

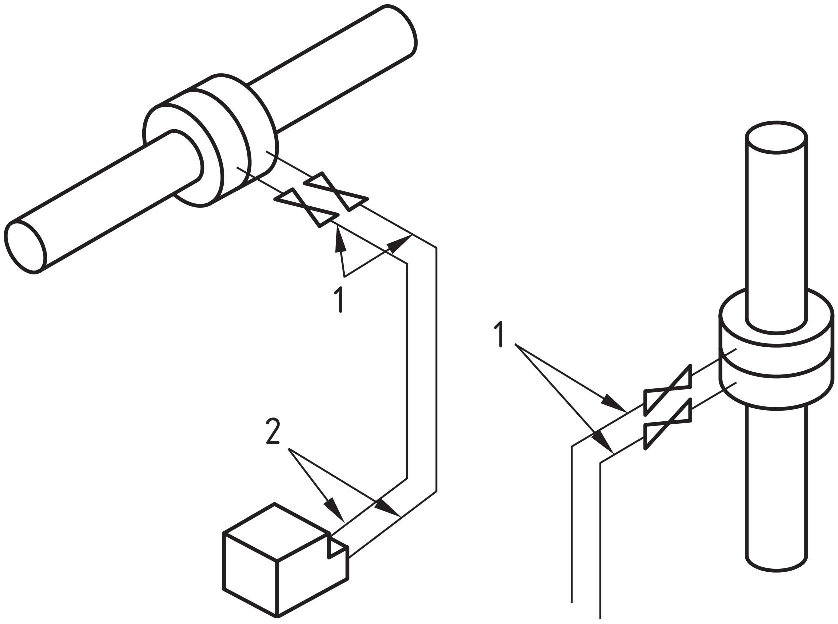
7.1.2.2.5 Vertical lines

Where metering orifices are installed in vertical lines, the direction of flow should preferably be upwards for liquids and downwards for gases. This practice obviates the need for drain or vent holes in the primary element.

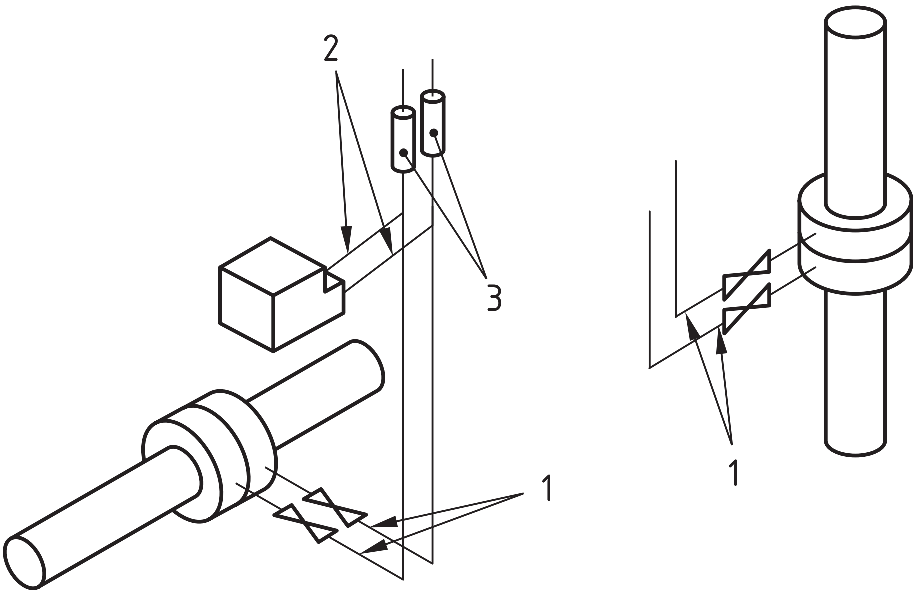
7.1.2.2.6 Impulse pipework connections

Connections between the tapping points and the differential pressure measuring devices should be as short as possible and should conform to **7.2.2**. Examples of arrangements are shown in Figures 6 to 10. Where impulse lines are situated in areas where the ambient temperature could approach the freezing or pour-point of the measured fluid, the lines should be suitably thermally insulated or heat traced. All impulse/transmitter valves should be of suitable material and rating for the pipeline service.

Figure 6 **Typical impulse pipework connections for measurement of flow of liquid**



a) Preferred arrangement: instrument is mounted below tapping points



b) Alternative arrangement if instrument has to be mounted above tapping points

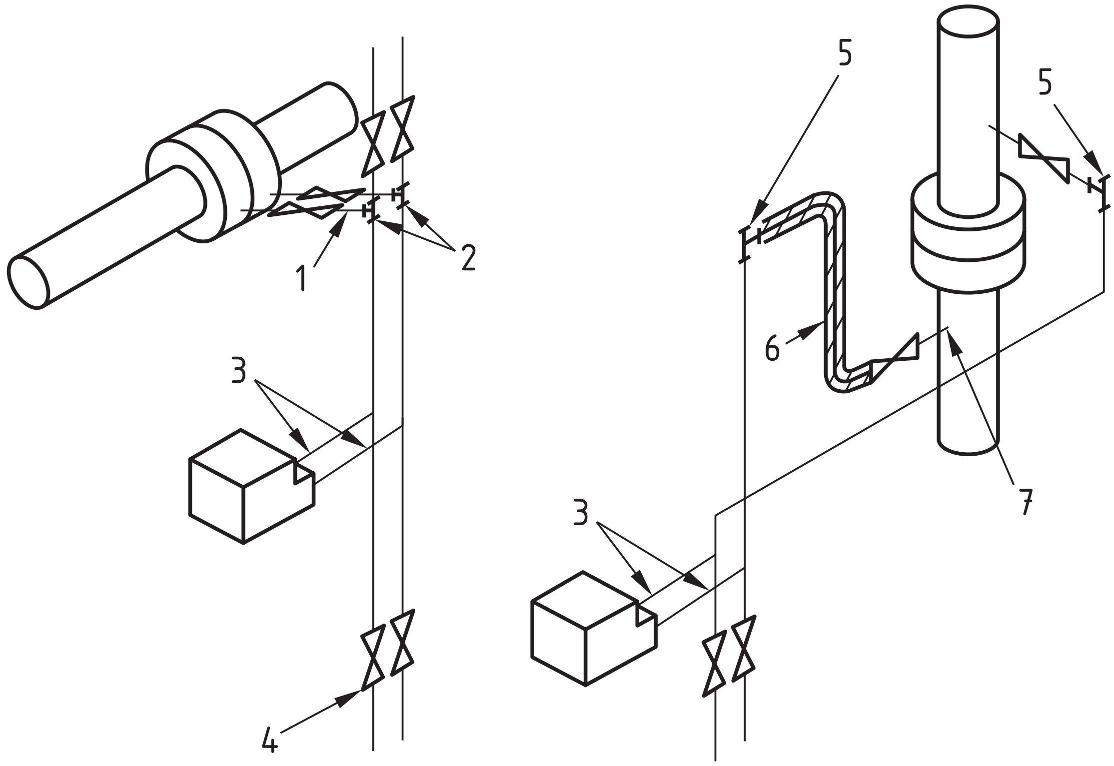
Key

1 Impulse lines fall from pipe by 1 in 10

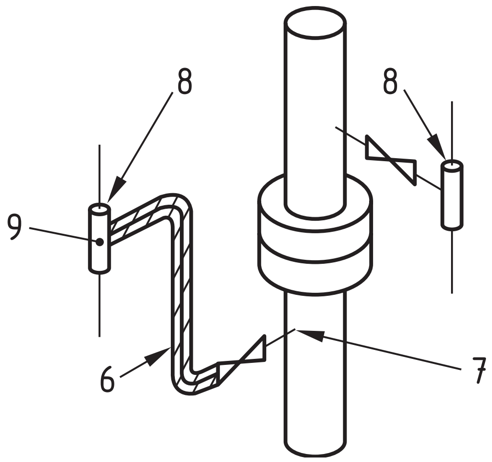
2 Impulse lines fall to transmitter by 1 in 10

3 Vent chambers

Figure 7 **Typical impulse pipework connections for measurement of flow of steam or condensing vapour**



a) Preferred arrangement: instrument is mounted below tapping points



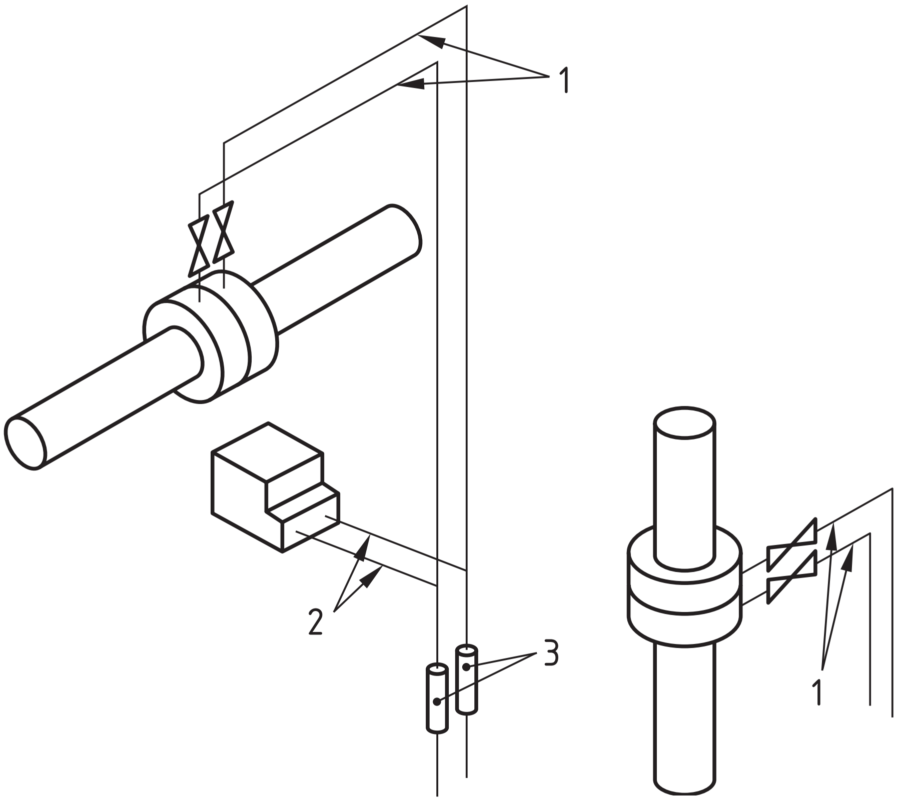
b) Alternative arrangement if instrument has to be mounted above tapping points

NOTE Pipes marked to slope downward in direction of arrow.

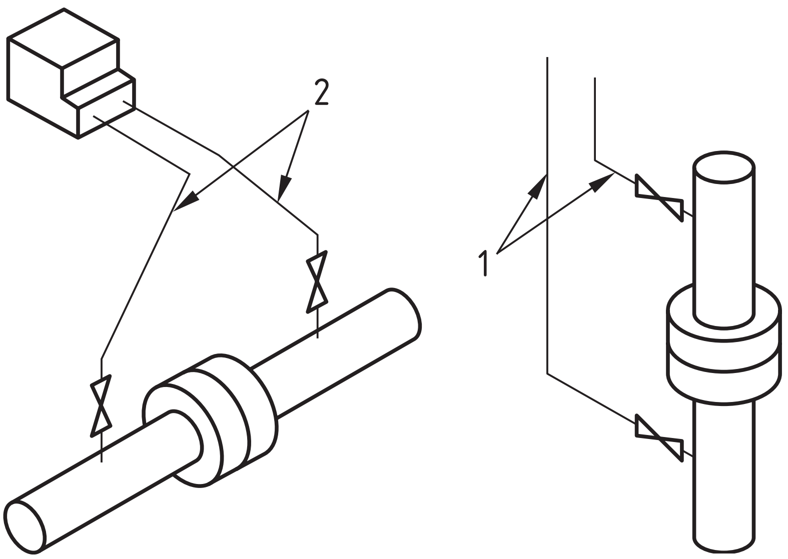
Key

1 Impulse lines rise from pipe by 1 in 10
2 Filling tees
3 Impulse lines fall to transmitter by 1 in 10
4 Blowdown valve
5 Filling tees at same level
6 Thermal insulation essential
7 Minimum tapping size 12 mm
8 Condensate parts at same level
9 No insulation around condensate pot

Figure 8 **Typical impulse pipework connections for measurement of flow of gas**



a) Arrangement for instrument mounted below tapping points



b) Arrangement for instrument mounted above tapping points

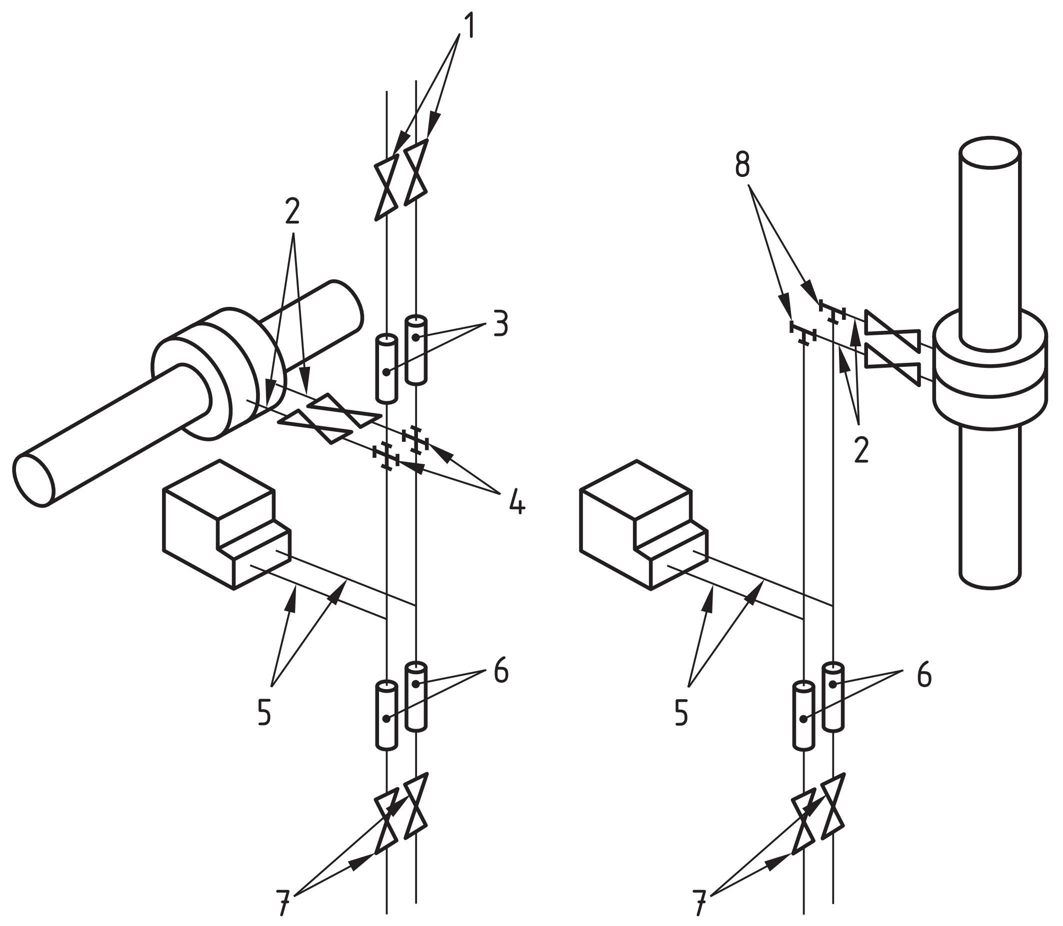
Key

1 Impulse lines rise from pipe by 1 in 10

2 Impulse lines rise to transmitter by 1 in 10

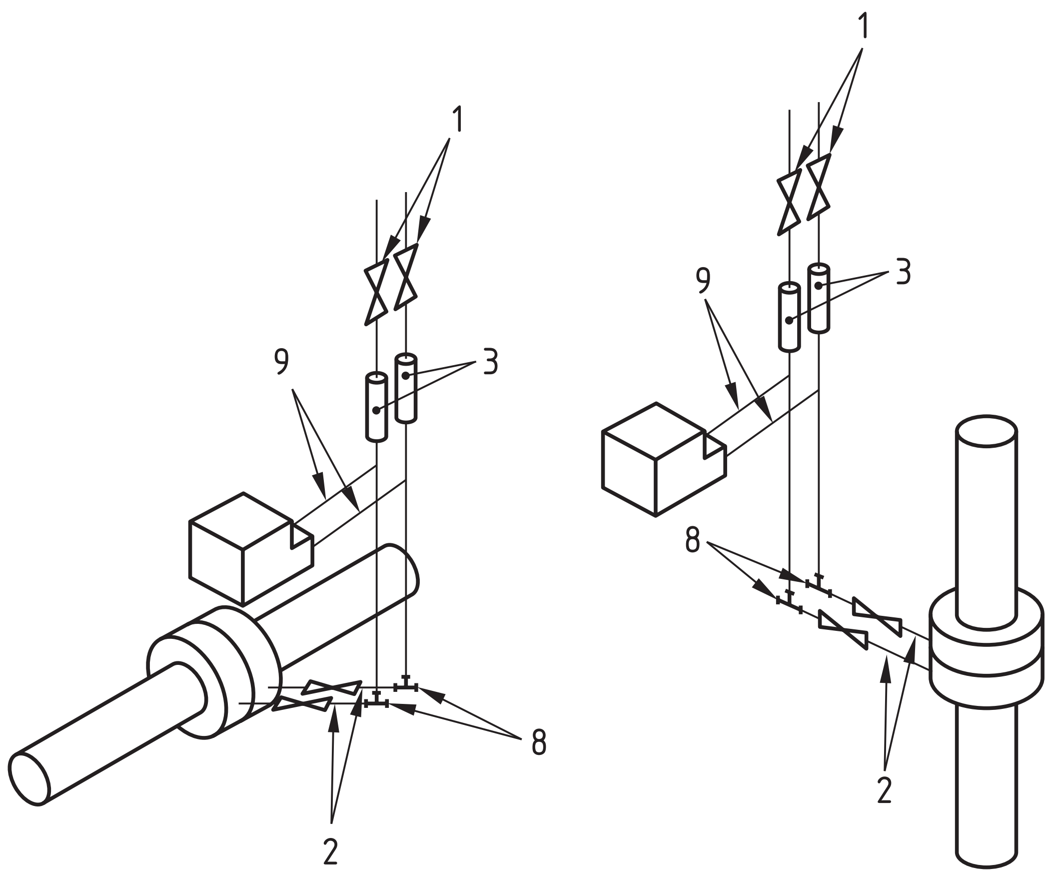
3 Separating vessels necessary for wet gas

Figure 9 **Typical impulse pipework connections for measurement of flow of liquid with suspended material**



a) Preferred arrangement: instrument is mounted below tapping points

Figure 9 **Typical impulse pipework connections for measurement of flow of liquid with suspended material** *(continued)*

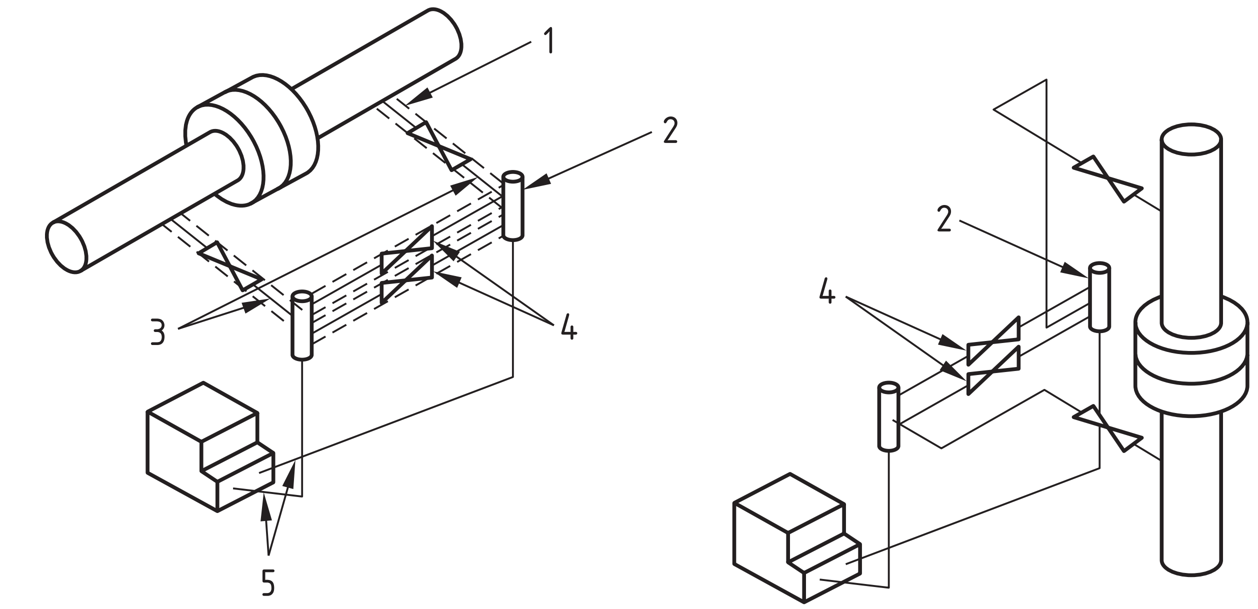


b) Alternative arrangement if instrument has to be mounted above tapping points

Key

1 Vent valves
2 Impulse lines rise from pipe by 1 in 10
3 Vent chambers
4 Rodding connections – cross with removable plug
5 Impulse lines rise to transmitter by 1 in 10
6 Settling chambers
7 Drain valves
8 Rodding connections – tee with removable plug
9 Impulse lines fall to transmitter by 1 in 10

Figure 10 **Typical impulse pipework connections for measurement of flow where seal pots are used (orifice plate)**



NOTE Lag and heat trace seal pots and pipe connections if liquid is prone to congealing

Key

1 Heat tracing

2 Seal pots at same level

3 Impulse lines fall from pipe by 1 in 10

4 Equalizing valves

5 Impulse lines fall to transmitter by 1 in 10

7.1.2.2.7 Condensate pots

For the measurement of steam or condensing vapours, appropriate condensing devices should be provided at the tapping point. For large displacement instruments, condensate pots should be fitted. For instruments with negligible displacement, such as differential pressure cells, filling tees of about 35 mm bore have adequate capacity. Examples of pipework arrangements are shown in Figure 7.

If the process temperature exceeds 400 °C, vaporizing vessels should be incorporated into the pipework arrangements.

7.1.2.2.8 Wet gas drains

Impulse lines for flow measurement of wet gases should incorporate drain vessels and valves and should slope to ensure drainage. Drain disposal lines, if required, should be of adequate size to avoid excess back pressure (see Figure 8).

7.1.2.2.9 Vents and rodding points

Liquid flow measurement installations should be arranged to prevent gases or suspended material collecting in the impulse pipework. The exact configuration for any particular application will depend on the nature and concentration of the suspended material, the quantity of entrained gas present and the active volume of the measurement transducer. Where solid matter is suspended in the liquid, rodding facilities might be required to clear tapping points. Where the vented gases might be combustible or otherwise hazardous, the vent line should be led to the specified location or to an adjacent well ventilated point.

7.1.2.2.10 Seal pots and diaphragm seals

Where it is necessary to protect the differential pressure transducer from process conditions (e.g. viscous or corrosive fluids and suspended solids or powders), seal pots or remote diaphragm seals should be fitted. Arrangements for impulse pipework with seal pots are shown in Figure 10.

Diaphragm seals are supplied connected to the differential pressure transducer by a fixed length of capillary tubing filled with a special oil, usually silicone based. The transducer's calibration is usually selected for a given mounting position relative to connection points. If this has to be modified, e.g. due to site changes, the elevation or suppression of the transducer's range should be changed accordingly. The span of the instrument should not be changed.

If the capillary is found to be shorter than required, site modification is not possible and the transducer should be returned to the manufacturer for modification.

7.1.2.2.11 Pitot tubes

NOTE Caution should be exercised if quick-release connections are used.

Connections to a differential pressure pitot tube installation usually include flexible connections to allow a traverse across the pipe to obtain an average velocity measurement. Such connections are shown in Figure 11. Averaging and amplifying pitot tubes have several impact tubes and therefore do not require traversing facilities. In this case the flexible connections may be omitted unless otherwise specified in the original design drawing.

Electronic pitot tubes should be installed in accordance with the manufacturer's instructions.

7.1.2.3 Installation

7.1.2.3.1 General

Many problems with flow measuring devices are caused by dirt and foreign matter left in the lines after installation. Consequently the proper sequence of cleaning and assembly should be followed to minimize difficulties.

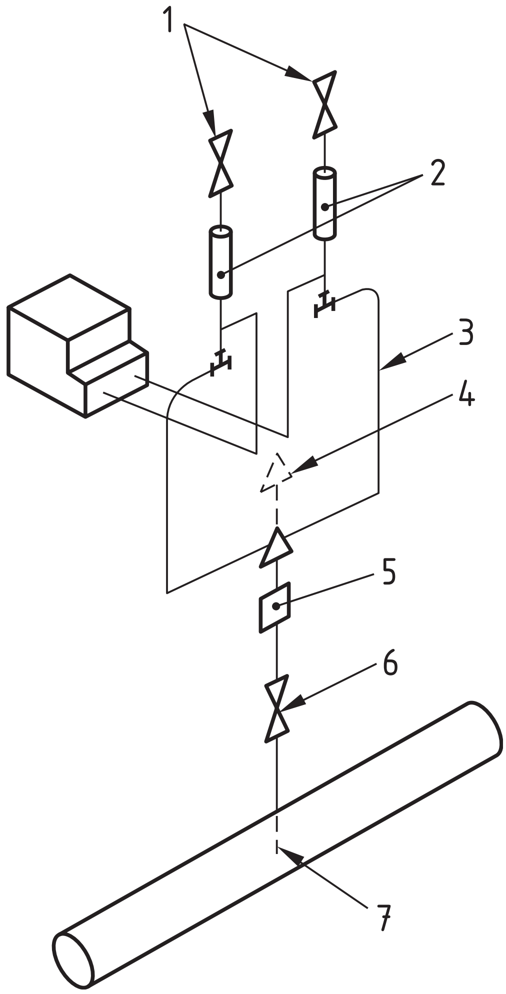
7.1.2.3.2 Tapping connections

Where tapping connections are to be made into the pipe, the bosses should be fitted and drilled before the lines are cleaned. Bosses should be drilled after welding. Taps in flanges should be drilled and deburred as necessary.

7.1.2.3.3 Cleaning and purging

The pipework upstream of the flow measuring primary elements should be descaled and flushed with the primary devices omitted and spool pieces used where necessary for pipework continuity. Where descaling is not possible, other approved cleaning techniques should be used to clear the line of dirt and foreign matter.

Figure 11 **Typical arrangement of differential pressure pitot tube installation for measurement of liquid flow**



Key

1 Vent valves
2 Vent chambers
3 Flexible hose
4 Partially withdrawn position
5 Gland seal
6 Gate valve
7 Inserted position

7.1.2.3.4 Mounting

7.1.2.3.4.1 General

The flow measuring primary elements should be installed only after process pipework cleaning is complete.

In all cases the concentricity of the primary element with the pipe is important and where this is not ensured by the element construction, careful assembly is necessary to ensure concentricity.

It is important that the jointing materials used are of the specified type and thickness and do not project into the bore of the pipe.

7.1.2.3.4.2 Angle of mounting

Primary elements with integral tappings should be mounted in horizontal or sloping pipes so that the tappings are at the correct angle as shown in Figure 5.

Orifice plates in horizontal or sloping pipes should be located so that the vent and drain holes, if provided, can be positioned as follows.

a) *Gases and steam*. The drain hole should be at the bottom of the pipeline.

b) *Liquids*. The vent hole should be at the top of the pipeline.

Care should be taken to ensure that vent and drain holes are not obscured by the jointing material or the flange.

7.1.2.3.5 Direction of flow

In all cases the direction of flow should be checked and the primary device installed accordingly, e.g. square edged orifices with the square edge facing upstream and arrow markings on the Venturis pointing downstream.

7.1.2.3.6 Pitot tube alignment

Pitot tubes should be correctly aligned with the pressure port axis within 5° of the pipe axis or, in the case of large gas ducts, within 5° of the specified direction.

7.1.3 Variable area flowmeters

7.1.3.1 Principle

The most common type of variable area flowmeter operates on the principle that a loose float within a vertical tapered tube will assume a position where the differential pressure across the float is equal to its mass and this position is a function of the upward flowrate. Variable area orifice flowmeters incorporate a profiled plug which is sprung against the force of flow through an orifice. The movement of the plug is a measure of flow and is sensed electronically or pneumatically.

In high flow applications, float-type variable area flowmeters may be connected across a flow-sharing orifice plate or other differential pressure generator to form a bypass flowmeter. The primary element should be calibrated so that the flow through the variable area meter is a known proportion of the total flow rate.

7.1.3.2 Installation arrangement

7.1.3.2.1 Pipework layout

Float-type variable area flowmeters should be mounted vertically. They are not sensitive to flow disturbances caused by upstream pipework layout, and installations frequently include elbows adjacent to the meter.

Other types of variable area flowmeter are generally insensitive to flow disturbances resulting from pipework layout, but might have special requirements for layout defined by the manufacturer.

7.1.3.2.2 Bypass piping

Variable area meters should be installed in a manner that permits easy meter and float removal for repair purposes and, where specified in the original design, should be provided with a line size block and a bypass gate valve. Drain valves should be provided at the meter inlet in such installations.

7.1.3.2.3 Strainers

Small variable area flowmeters should be protected by a strainer to prevent jamming by pipe scale or foreign matter.

7.1.3.2.4 Location

The meter should be located where it is accessible for observation and maintenance, and in an area free from vibration.

7.1.3.3 Installation

7.1.3.3.1 Cleaning and purging

As for other flowmeters the pipework should be purged and cleaned before the meter is installed. However, if this is not possible, it is essential that the meter be removed temporarily while the pipework is cleaned.

7.1.3.3.2 Mounting and alignment

Alignment and support of adjacent pipework is important in the installation of variable area flowmeters to avoid distortion or damage. It is essential to avoid stressing the meter during installation. Care should be taken to ensure that the meter is installed vertically and retained in this position under operating conditions.

7.1.4 Positive displacement flowmeters

7.1.4.1 Principle

Positive displacement flowmeters measure flow by isolating, counting and totalizing segments of fluid of known volume as they pass through the meter.

Positive displacement flowmeters are used for gas and liquid measurement but certain types are unsuitable for measuring the flow of liquids laden with suspended particles.

7.1.4.2 Installation arrangement

Positive displacement flowmeters are not sensitive to pipework arrangement provided that throttling valves are not located immediately upstream of the meters. The pipework arrangement should not impose stresses on the flowmeter, and larger meters should either stand on the floor or be provided with a support structure. Strainers and vapour eliminators should normally be incorporated in the upstream pipework to obtain maximum accuracy and reliability of the measurement.

7.1.4.3 Installation

7.1.4.3.1 Pre-installation inspection

When the meter is received on site it should be inspected.

> **CAUTION.** If the manufacturer's flange seal has been disturbed, care should be taken to ensure that the inlet and outlet ports are free from packing or foreign matter, as such material entering the measuring chamber can cause serious damage.

The process connections should then be completely sealed until the meter is required for installation in the line.

7.1.4.3.2 Cleaning and purging of pipework

Prior to installing the meter, strainers, filters or gas eliminators, the pipework should be thoroughly descaled and flushed, where necessary, with a suitable liquid.

7.1.4.3.3 Mounting and alignment

The strainers, filters, vapour eliminators, etc., should be installed in the pipe and the dimensions between the final meter connections should be carefully checked, allowing for joint rings where applicable. The flange seals should be removed and cleanliness of the ports checked. The meter should then be installed ensuring that the direction of flow is correct and that the dials of the local integrating mechanism, if fitted, are correctly located. Normally these dials are on the top of the meter.

7.1.5 Turbine flowmeters

7.1.5.1 Principle

A turbine flowmeter comprises a turbine rotor mounted on bearings along the axis of the pipe which is forced to rotate by the movement of the process fluid. The rotation of the turbine rotor is indicated by a mechanical or an electronic output.

7.1.5.2 Installation arrangement

7.1.5.2.1 Pipework layout

The accuracy and repeatability of a turbine flowmeter is especially dependent upon upstream and downstream piping arrangements. In addition to sufficient upstream and downstream straight runs, a flow straightener is often required if the potential accuracy of a turbine meter is to be achieved.

7.1.5.2.2 Location

The turbine flowmeter should be installed in process pipework that is free of vibration. Turbine flowmeters are generally installed in horizontal lines. Certain types may be mounted in vertical lines but special calibration would be required.

7.1.5.2.3 Strainers

Generally, all turbine flowmeter installations should be fitted with strainers upstream to prevent foreign matter from damaging the device or blocking the flow passages.

7.1.5.2.4 Gas eliminators

For maximum accuracy and reliability of measurement of liquid flow, means should be provided for automatic removal of gas in the upstream pipework.

7.1.5.2.5 Operating pressure

Turbine flowmeters in liquid service should operate with sufficient pressure to prevent cavitation and avoid the resulting errors or damage.

7.1.5.2.6 Electrical connections

The low level signals generated by some transducers are prone to interference. The manufacturer’s instructions for electrical installation should be followed.

7.1.5.3 Installation

7.1.5.3.1 Cleaning and purging

The flowmeter should be installed only after the process pipework has been cleaned and flushed. If strainers are used they should be cleaned after flushing and periodically during operation. Pressure testing should be carried out with the flowmeter installed.

7.1.5.3.2 Mounting and alignment

Prior to assembly, a check should be made that the flowmeter is correctly calibrated for the mounting attitude.

The pipework should be carefully aligned before fitting the flowmeter. When a flanged flowmeter is installed, the inside bore of any pipeline gasket should not project into the bore of the line. The flowmeter should be fitted with the direction of flow arrow on the casing pointing the correct way for the application.

7.1.5.3.3 Line filling

Flow should be introduced slowly to the flowmeter to prevent damage to the turbine blades by hydraulic impact or overspeed.

7.1.6 Vortex shedding flowmeters

7.1.6.1 Principle

Vortex shedding flowmeters measure the rate at which vortices are shed by a bluff body in the flow stream. The frequency of vortex shedding is proportional to flow velocity over a range of flow.

Signal output from the vortex sensor is converted by an integral or local signal conditioning unit to a pulse rate or current signal proportional to flow rate.

7.1.6.2 Installation arrangement

7.1.6.2.1 Pipework arrangement

Vortex flowmeters are sensitive to pipework arrangement, particularly upstream and immediately downstream of the meter. The manufacturer’s recommendations for the pipework arrangement should be followed, particularly as the arrangement varies significantly with the type of vortex transducer and its application.

7.1.6.2.2 Location

Vortex flowmeters may be installed in vertical or horizontal pipe runs. The pipe should be adequately supported and should not be subject to vibration.

7.1.6.2.3 Electrical connections

The low level signals generated by some vortex shedding sensors are prone to interference. The manufacturer s recommendations for maximum cable length and type should be followed.

7.1.6.3 Installation

7.1.6.3.1 Cleaning and purging

The vortex flowmeter should be installed only after the process pipework has been cleaned and flushed. The pipework should be pressure tested after meter installation.

7.1.6.3.2 Mounting and alignment

When the flowmeter is installed, the inside bore of any gasket should not project into the bore of the line. It should be ensured that the flowmeter is mounted so that the direction of flow arrow on its casing points the correct way for the application.

7.1.7 Open channel flow measurement

7.1.7.1 Principle

Measurement of flow in open channels is similar to differential pressure flow measurement except that the head of fluid flowing over the crest of a weir or through a flume is related to the rate of flow.

Various designs of weir or flume are used, which fall into four general types:

a) thin-plate notch weirs;

b) broad-crested weirs;

c) Venturi and standing wave flumes;

d) compound weirs or flumes.

Each of these types may incorporate different geometries of the weir or flume section.

Often, open channel flow measurements are on large flows where the major parts of the works associated with the weir or flume are constructed in concrete as a civil engineering operation. For smaller flows, prefabricated flumes or thin plate weirs are used and the erection of these should be supervised since accuracy of measurement is significantly affected by errors in installation. The location and installation of head measuring devices are particularly important.

7.1.7.2 Installation arrangement

7.1.7.2.1 Location

All weirs and flumes require steady upstream flow conditions to give predictable performance. Where the approach channel is very much larger in section than the weir or flume, its shape is generally not significant. In other situations the approach channel should have a smooth straight section of at least 10 times the maximum width of the weir or flume.

The slope of the approach channel should be sufficiently slight to avoid a standing wave developing in the approach channel. If this is not possible the detailed recommendations given in BS 3680 should be followed.

Downstream conditions should be such that the tail water level does not build up to drown the weir or flume under operating conditions. To achieve this the downstream channel bottom should be no higher than that specified in BS 3680 for the weir or flume type employed. Where a weir or flume is designed to operate drowned, special conditions apply (see BS 3680).

7.1.7.2.2 Head measurement facilities

The head generated by a weir or flume may be measured by most of the methods described in **7.5**. Most commonly, open channel water levels are measured by means of displacement devices in gauge wells or by differential pressure or ultrasonic level sensors.

Generally, only one measurement of head is required, but where weirs are designed to operate drowned, a second level measurement at the weir crest is used. In triangular profile weirs or flat-V weirs this second head measurement is located at the weir crest

The head measurement location depends on the weir or flume type employed.

The head measurement locations for different types of weir or flume are given in the following parts of BS 3680:

a) thin-plate notch weirs: BS 3680-4A;

b) triangular profile weirs: BS 3680-48;

c) rectangular, trapezoidal or U-throated flumes: BS 3680-4C;

d) compound weirs: BS 3680-D;

e) rectangular-profile weirs: BS 3680-E;

f) round-nose orlzonta crest weirs: BS 3680-F;

g) flat-V weirs: BS 3680-4G.

7.1.7.3 Installation

7.1.7.3.1 Pre-installation inspection

Prefabricated flumes and notch weir plates should be examined to ensure that the flume or notch is free from dents, burrs or other damage as these will affect accuracy.

7.1.7.3.2 Alignment

Prefabricated flumes and notch plates should be aligned carefully before they are fixed in the channel. The devices should be centrally located in the channel, level both across and along the channel. In all cases the manufacturer's instructions should be followed.

Where the weir or flume is not prefabricated, the dimensions and geometry of the structure should be checked. For tolerances on dimensions to obtain a given accuracy, see BS 3680. Where dimensional errors are excessive, remedial work should be carried out to obtain the desired accuracy.

7.1.7.3.3 Setting zero flow

The zero flow datum should be accurately set on site so that there is no systematic error in the measurement of head. The method of setting the zero level depends on the type of weir, and the appropriate method described in BS 3680-4 should be followed.

7.1.7.3.4 Head sensing device

The head sensing device should be installed in accordance with the appropriate subclauses of **7.5**.

Particular care should be taken to maintain proper clearances between displacer elements and the sides of the gauge well.

7.1.8 Electromagnetic flowmeters

7.1.8.1 Principle

Electromagnetic flowmeters function by measuring the voltage induced in a liquid flowing through a magnetic field. A flowmeter is installed in the process pipe and the signals generated are processed by an integral or remote transducer.

7.1.8.2 Installation arrangement

7.1.8.2.1 Location

The electromagnetic flowmeter averages the velocity profile across the pipe so that it is not particularly sensitive to upstream or downstream piping arrangements. However, for accuracy, the manufacturer's instructions should be followed.

The flowmeter unit may be installed in pipework in any position (vertical, horizontal or at any angle) but it should remain full of liquid at all times to ensure accurate measurement. When mounted horizontally the electrode axis should not be in a vertical plane. The electromagnetic flowmeter should normally be mounted where the instrument is not subjected to vibration nor exposed to ambient conditions outside its specified limits.

7.1.8.2.2 Pipework support

Normally, magnetic flowmeters up to 300 mm bore require no extra support than that provided for a similar length of pipe. For larger sizes the manufacturer's recommendation for support structures should be followed.

7.1.8.2.3 Electrical requirement

For predictable measurement it is essential that the process liquid be at earth potential. This may be achieved by earthing metallic pipework, or by the use of metallic earthing rings, probes or gaskets where the process pipework or its lining is non-conductive. Earthing arrangements should follow site practice as far as possible. Nevertheless, it is essential that the manufacturer's instructions for earthing are followed.

Electrical connections between the flowmeter and the transducer should not exceed the maximum distance permitted by the manufacturer.

7.1.8.2.4 Cathodic protection

If the detector head is installed in a system that is cathodically protected or where electrolysis is used in the process, special precautions should be taken to ensure that:

a) current at supply frequency does not flow through the liquid in the detector head;

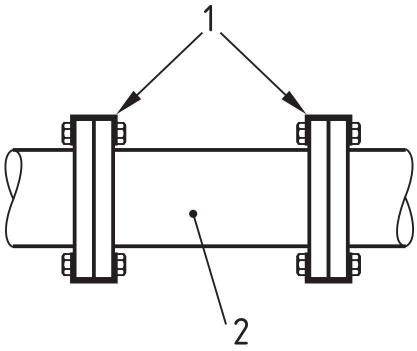
b) any current, at supply frequency, flowing through the body of the detector head does not exceed 10 A r.m.s.

These precautions are intended to limit the magnitude of any spurious magnetic fields.

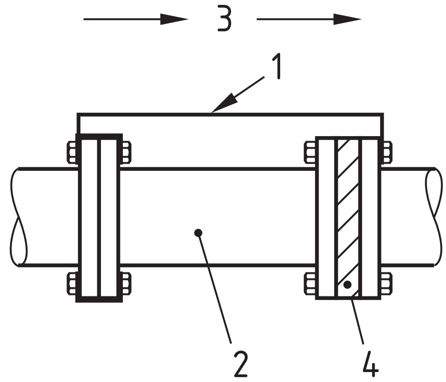
In systems where a metal pipeline without an insulating liner is used, the liquid in the system can be placed at earth potential by bonding the detector head to the adjacent pipeline as shown in Figure 12a). This arrangement should only be used for systems where it is known that any current flowing through the body of the detector head does not exceed 10 A r.m.s. If the current flowing through the body of the detector head exceeds 10 A r.m.s., the detector head should be bonded to the adjacent pipeline as shown in Figure 12b).

When bonding the detector head flanges, flange bolts should not be relied upon as electrical connectors. Troublesome potential differences can occur in systems where, for example, a cathodically protected pipeline joins a grid system, not quite at earth potential, or joins an earthed pumping station. In these cases it might be necessary to insert short lengths of unlined pipework bonded to the detector head as shown in Figure 12c). The length of these sections will depend upon the magnitude and ripple content of the cathodic voltage and upon the nominal bore of the pipeline.

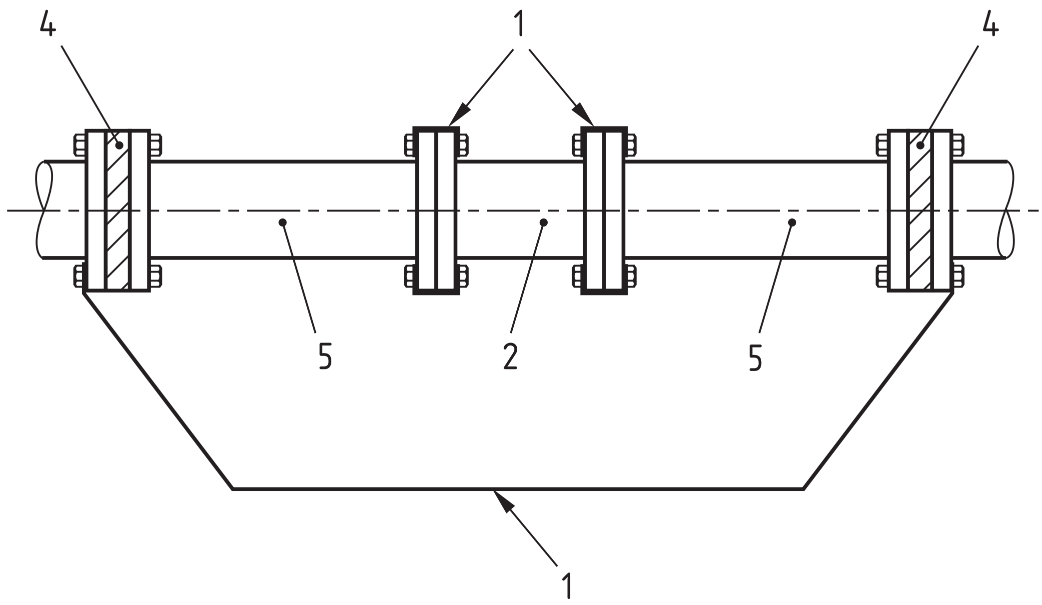
Figure 12 **Typical cathodic protection**



a) Detector head bonding



b) Detector head bonding using insulating flange



c) Detector head bonding using unlined pipe sections

Key

1 Bond
2 Director head
3 Current
4 Insulating flange
5 Unlined pipe

7.1.8.3 Installation

7.1.8.3.1 Storage

The flowmeter and transducer should be stored in a clean dry area until required for installation, and protective covers should not be removed until necessary to permit erection of the equipment. The flowmeter should be stored in its packing or in a cradle; it should never be stood on its end flanges. The flowmeter is a precision-built instrument and should be treated as such.

7.1.8.3.2 Handling

Although the flowmeter appears to be a robust pipe spool, care should be taken in handling it to avoid damage, particularly to the liner. Lifting should always be accomplished with slings. A bar threaded through the flowmeter should never be used for lifting. If the liner is damaged during handling, it should be repaired or replaced using an approved procedure before the flowmeter is installed.

7.1.8.3.3 Cleaning and purging

The flowmeter should be installed only after the process pipework has been cleaned and flushed. The pipework should be pressure tested after the flowmeter has been installed.

7.1.8.3.4 Mounting

Care should be exercised during installation to avoid damage to the flowmeter and its lining. Where the liner is brought out over the flange face, the liner should not be forced between flange faces but a suitable gasket should be installed between the pipe and the flowmeter flanges. Such a gasket should not protrude into the bore of the pipe.

During installation it is essential to avoid undue stress on the flowmeter. It is desirable to bolt the flowmeter to its upstream and downstream pipework before completing pipework assembly at a flange remote from the flowmeter. Care should be taken to align the flowmeter with its adjacent flanges, and the fixing bolts should be tightened evenly.

7.1.8.3.5 Electrical connections

Special low capacitance cable, in accordance with manufacturer's instructions, should be used when the flowmeter does not incorporate an integral transducer. Such connecting cable should not be installed close to power cables nor share a common conduit with power supply wiring.

7.1.8.3.6 Earthing

The instrument manufacturer's recommendations for earthing should be followed during installation.

7.1.9 Ultrasonic flowmeters

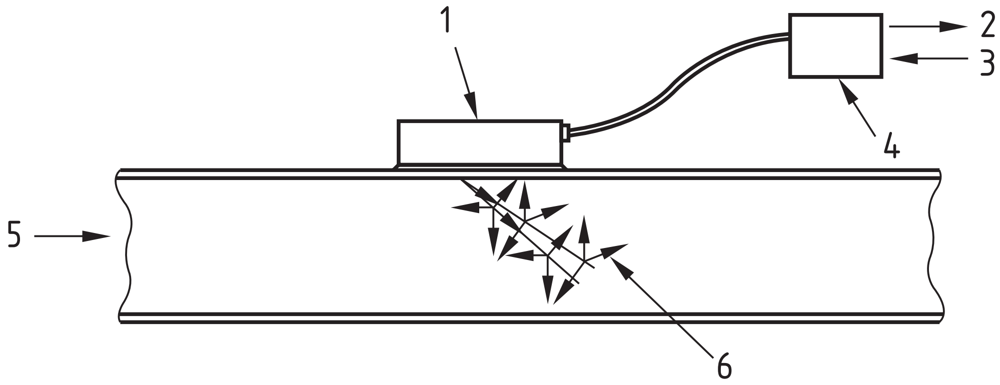
7.1.9.1 Principle

There are two main types of ultrasonic flowmeter employing different principles to measure flow, i.e. doppler and transit time.

For each of these methods of measurement there are variations for different applications. These include the use of different paths and layouts, e.g. direct or zigzag across the pipe and more sophisticated measurement techniques to give better accuracy.

Examples of arrangements for both types of ultrasonic flowmeter are shown in Figure 13 and Figure 14.

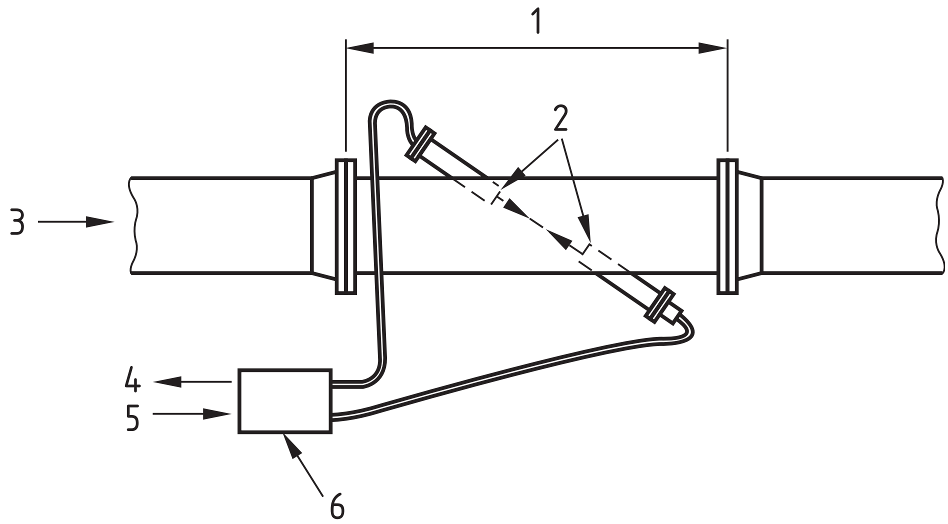
Figure 13 **Example of ultrasonic Doppler flow measurement**



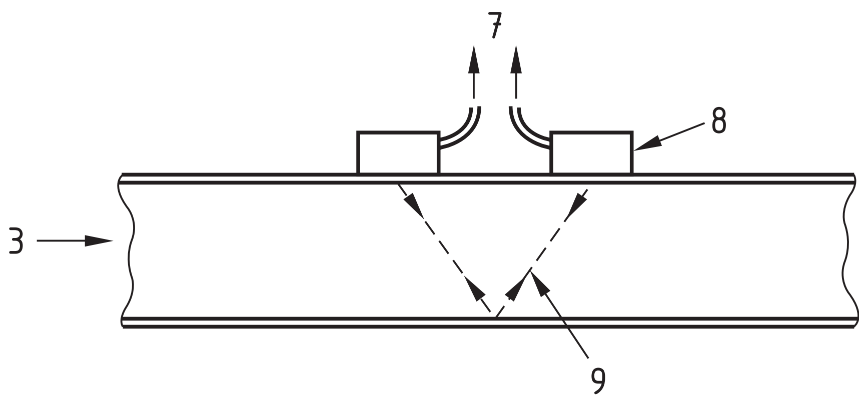
Key

1 Transmitter/receiver sensor
2 Output
3 Power supply
4 Electronic unit
5 Flow
6 Ultrasound beam scattered and reflected by particles and bubbles

Figure 14 **Example of ultrasonic transit time flow measurement**



a) Direct path arrangement



b) Reflex path arrangement

Key

1 Measurement section
2 Ultrasonic transmitter/receiver sensors in pocket inserts
3 Flow
4 Output
5 Power supply
6 Electronic unit
7 To electronic unit
8 Externally mounted transmitter/receiver sensors
9 Transmit time of pulse altered by velocity of liquid

7.1.9.2 Installation arrangement

7.1.9.2.1 Location

Ultrasonic flowmeters are calibrated for a fully developed flow profile and errors are likely to occur when the flow profile at the point of measurement is disturbed. The manufacturer's recommendations should be followed, but for most types of ultrasonic flow meters, an upstream straight length of at least 10 pipe diameters should be allowed after bends or tees, and 20 diameters after throttling valves or an increase in pipe diameter.

Installations using multi-path transit time methods require much shorter upstream straight lengths. Minimum lengths should be indicated at the design stage.

Ultrasonic flowmeters sense vibration or noise generated in cavitating valves and they should be located on a vibration-free section of piping as remote as possible from any upstream or downstream valve where cavitation noise might be generated.

7.1.9.2.2 Pipework

Ultrasonic flowmeters may be pre-assembled on a short length of pipe or the flow meters may be fixed to a suitable section of pipework by clamps, adhesives or as inserts in pockets. For some applications and types of flowmeter the sensor is mounted on a block or bar fixed to the pipe.

Ultrasonic sensors may be mounted on the outside of suitable rigid unlined metal or plastics pipe. For these applications it is essential that the bore of the pipe is accurately known and that it is reasonably smooth and free from deposits. In all cases the manufacturer's instructions should be followed.

To minimize errors from entrained gases or from solid deposits, the ultrasonic sensors should generally be arranged in a horizontal plane across the pipe.

7.1.9.2.3 Electrical connections

The connecting cable between the ultrasonic sensors and electronic units is usually prefabricated as part of the sensor and is often of special construction. The length of cable permitted between sensor and electronic unit is generally limited, and the manufacturer's instructions should be followed.

The electrical signals employed are at a low level and can be prone to interference. Consequently, connections should be kept short and should be routed away from other cables which might be sources of interference.

The electronic unit should be mounted in an accessible location suitable for the temperature rating of the equipment.

7.1.9.3 Installation

7.1.9.3.1 Pipework preparation

Good coupling of ultrasonic waves between the sensor and the fluid being metered is necessary to ensure reliable measurement. Externally mounted sensors should be fixed to a carefully prepared area on the outside of the pipe. Instructions should be followed for the use of adhesives or coupling jelly to obtain good performance. Where the sensor is mounted on a rod or block, the fixing of both the block to the pipe and the sensor to the block should be in accordance with the manufacturer's instructions.

7.1.9.3.2 Mounting and alignment

Where two separate sensors are employed, the relative positions of the two devices on the pipework should be carefully checked before permanently fixing in accordance with the manufacturer's instructions.

7.1.9.3.3 Prefabricated flowmeters

Where ultrasonic sensors are mounted on a prefabricated section of pipe, this section should be assembled with the pipework. Suitable jointing materials should be used and care should be taken to avoid jointing material projecting into the bore of the pipe.

7.1.9.3.4 Cleaning and purging

Externally mounted ultrasonic sensors are not affected by cleaning or purging processes provided that fluid temperatures do not exceed the rating of the sensors.

Means should be provided for the removal of sensor elements in contact with the process fluid when these are likely to be damaged by cleaning operations. The manufacturer's instructions should be followed.

7.1.9.3.5 Electrical connections

Electrical connections should be made in accordance with the manufacturer's instructions.

7.1.10 Coriolis mass flowmeters

7.1.10.1 Principle

The meter operates by diverting the fluid through two parallel flow tubes which are vibrated at their natural frequency. The forces induced by the fluid on the sensor tubes cause them to twist. This twist is directly proportional to mass flow and is sensed by magnet position detectors which feed the lag and lead data to electronics for processing into suitable output signals.

7.1.10.2 Installation arrangement

7.1.10.2.1 Location

The sensor should be at least 0.6 m from any large transformer, motor or other large interfering electromagnetic field.

Although normal vibrations are not a problem, areas susceptible to high vibration, e.g. motors or pumps, should be avoided.

When measuring gas flow, the equipment should be installed in such a way as to prevent accumulation of condensate within the flow tubes.

When measuring liquid flow, the equipment should be installed inverted so that the case is below the pipeline, thereby avoiding the trapping of air in the tubes.

When measuring liquid slurries, the sensor should be installed in a vertical line to avoid particle accumulation in the flow tubes. This facilitates cleaning if process lines are purged with gas or steam.

It is important to ensure that vapour/air cannot collect in the meter (for liquid applications) during zero flow, nor be present in large quantities during normal operation.

7.1.10.2.2 Pipework

Good piping practices should be observed during meter installation. For best results, pipe supports should be provided near the flange connections. The fluid fittings should not be used as pipe supports. Inlet and outlet piping should be installed using appropriate anchors, guides, expansion joints, hangers or other mechanical support systems. For smaller units, the process piping should be secured to the same mounting surface as the sensor units. On larger meters, which are installed directly in-line, additional pipe supports should be placed near the first elbow in the process line, or 10 to 20 pipe diameters from the fluid fittings.

A downstream shut-off valve is recommended to ensure actual flow when setting the primary zero adjustment.

In batching operations the flowmeter and shut-off valve should be located as close as possible to the receiving tank to minimize errors.

No special pipe configurations (straight pipe, elbow, etc.) are required.

7.1.10.2.3 Electrical connections

The manufacturer's instructions should be consulted to determine the maximum distance permitted between sensor and flow tube assembly.

The electronic unit should be mounted in an accessible location suitable for the temperature rating of the equipment.

Electrical connections should be made in accordance with the manufacturer's instructions.

7.1.11 Flow sensors

Most of the types of flowmeter described above may be used as a flow switch, e.g. a differential pressure sensor may be connected across an orifice or a variable area meter may incorporate limit switches to operate at a certain flow. For these types of device the appropriate subclause concerning installation should be followed. Other types of flow switches include those which operate on the principles of heat loss to a flowing fluid or changes in temperature gradient induced by a heater placed in the fluid.

There are some devices used as flow switches that are not normally used as flowmeters. These are often variable area devices providing both a visual indication and a switch output, e.g. the flap flow switch.

Other devices use an orifice or nozzle to generate head to operate an integral differential pressure switch; flow switches of this type should be installed in the same way as primary elements for differential pressure flowmeters. The manufacturer's instructions should be followed to ensure that the flow switch is mounted in the correct attitude for operation.

7.2 Pressure

7.2.1 General

The recommendations for the installation are largely independent of the type of pressure measuring device employed.

Materials of sensing elements should be selected to resist corrosion by the process fluid and the mounting environment and are typically stainless steel, bronze or monel.

Sensing elements should not be exchanged, even if they have the same range, without ensuring that the element material is as specified for the application.

7.2.2 Pressure connections

7.2.2.1 Tapping points

7.2.2.1.1 Independence

In general, a separate process connection should be provided for each instrument, especially where a pressure instrument performs a critical duty, such as forming part of an emergency trip system.

Latest practice might call for a number of impulse connections to use one process tapping. These will need special consideration, as a common isolating valve might not be appropriate and pressure tappings should not be shared with sampling devices. Combined sensors, such as pressure and temperature, are also available, but these will normally be direct mounted and not use impulse lines.

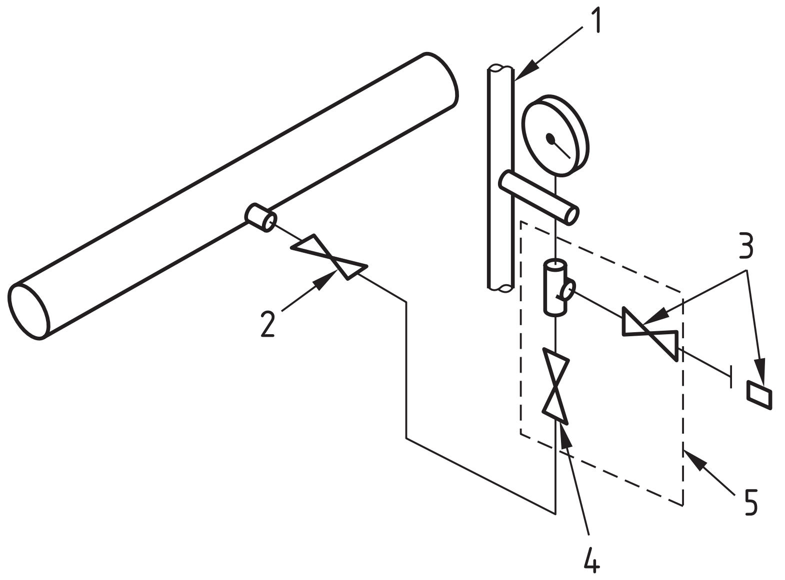
7.2.2.1.2 Radial location on horizontal or sloping pipes

The radial location of tapping points on horizontal or sloping pipe sections should take into account the nature of the process fluid as shown in Figure 15 and Figure 16. If other arrangements are adopted, additional facilities should be provided where necessary for draining or venting the impulse lines under fault conditions.

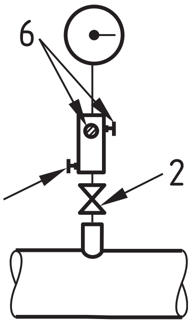
Provisions for flushing of impulse lines should be made where necessary.

Where solid matter is suspended in the fluid, rodding facilities should be provided where necessary to clear tapping points.

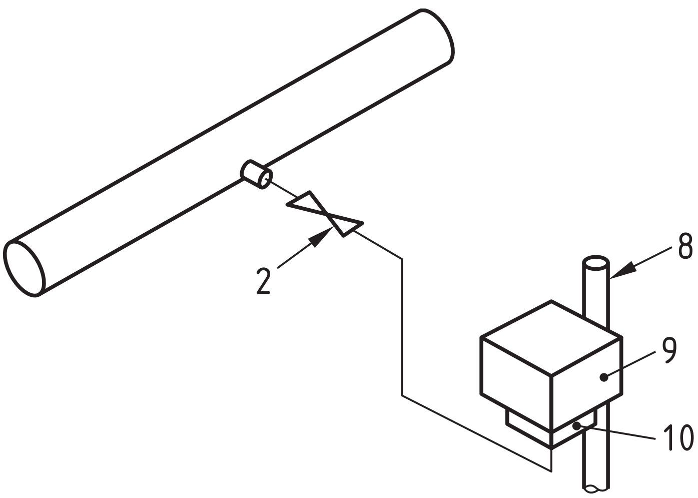
Figure 15 **Example of pressure indicator or transducer hook-ups for liquid measurement**



a) Basic indicator hook-up



b) Pressure gauge and gauge valve

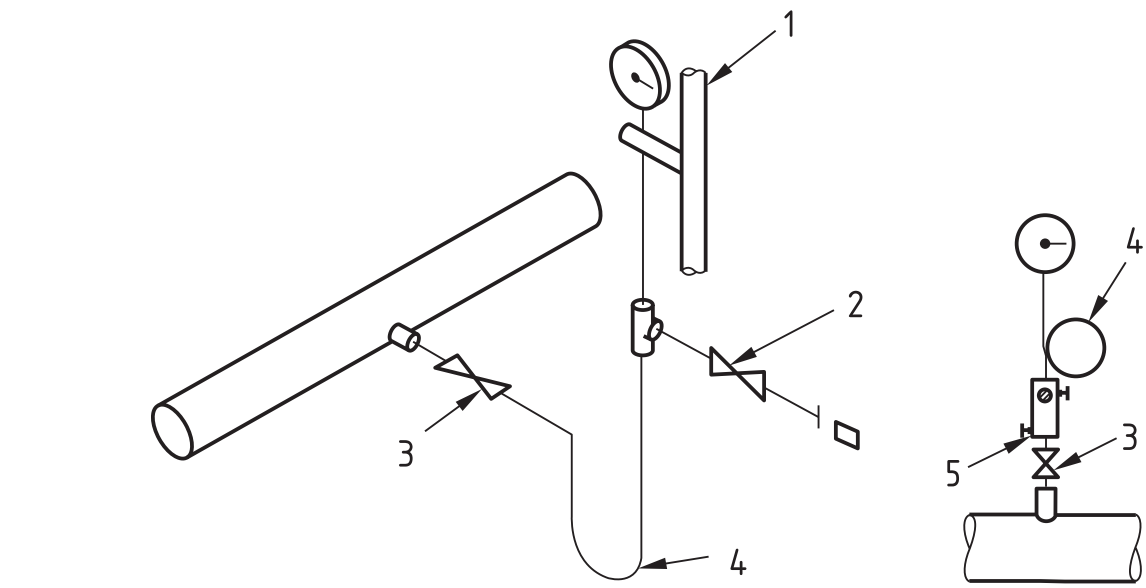


c) Pressure transmitter with combined block and vent/valve block

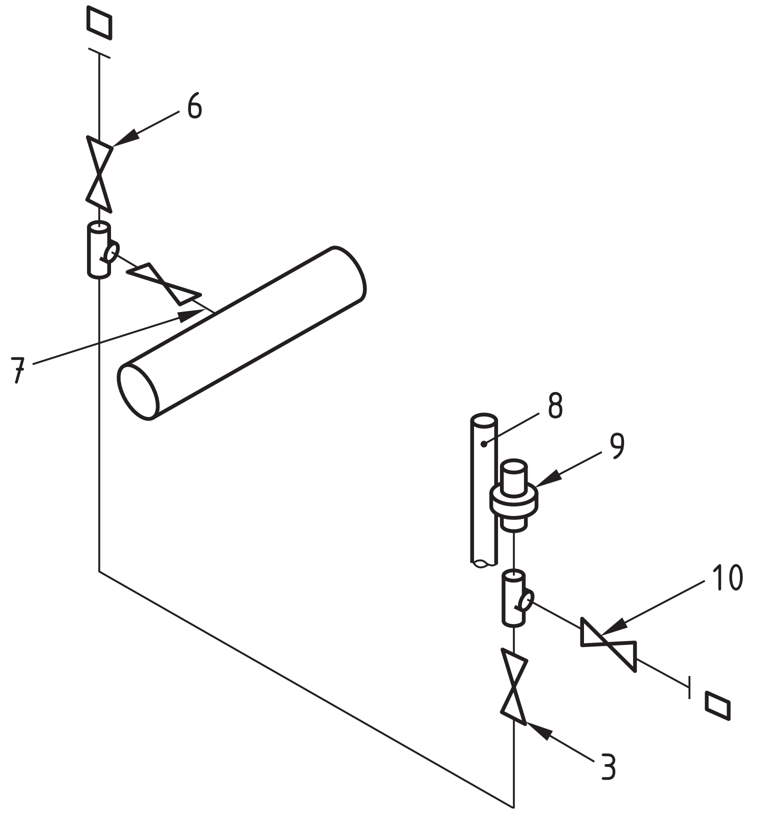
Key

1 Gauge support
2 Tapping point isolating valve
3 Depressurizing valve and removable sealing plug
4 Instrument isolating valve
5 Manifold
6 Depressurizing valve and sealing plug
7 Isolating valve
8 Transmitter support
9 Pressure transmitter
10 Block and vent manifold combined

Figure 16 **Example of pressure indicator or transducer with condensate seals for hot vapour or steam service**



a) Indicators with seal loops



Key

1 Gauge support
2 Depressurizing valve and removable sealing plug
3 Isolating valve
4 Condensate seal loop
5 Gauge valve
6 Filling valve and seal plug for low temperature vapour service (if specified)
7 Downward slope towards pipe tapping
8 Support tube
9 Sensing device below the level of the tapping
10 Depressurizing valve and seal plug

b) Transducer with filling tee

7.2.2.1.3 Installation

Tapping bosses should be fitted and drilled before the lines are cleaned. Bosses should be drilled after welding.

7.2.2.2 Impulse pipework

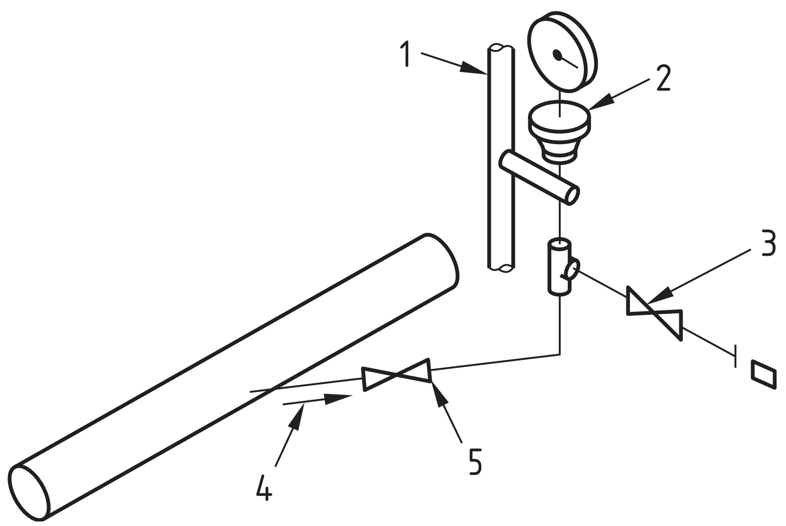
7.2.2.2.1 Arrangement

Examples of piping arrangements are shown in Figures 15 to 18. The impulse pipework should allow for any relative movement between tapping point and instrument due to expansion.

7.2.2.2.2 Protective seals

Condensate seals should be provided in piping to devices connected to steam or hot condensable vapour service (see Figure 16). Where the process fluid is particularly corrosive or has a high solids content, the instrument should be protected by seal chambers or diaphragm seals (see Figure 17). Where the process fluid is likely to congeal or become highly viscous at ambient temperatures, the impulse line should be heat traced and seal pots should be fitted to the instrument (see Figure 18). Where seals are used, the instrument should be calibrated taking into account the standing head or density of the seal fluid.

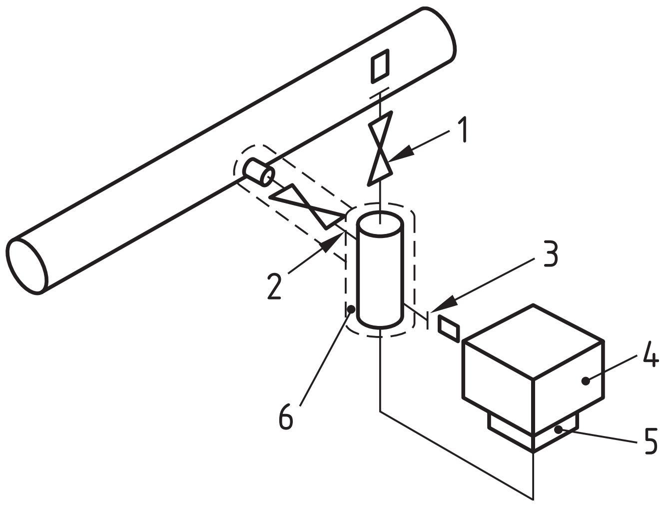
Figure 17 **Typical arrangement of pressure gauge with chemical seal**



Key

1 Gauge support
2 Chemical seal unit
3 Depressurizing valve and removable sealing plug
4 Slope upward to chemical seal unit
5 Isolating valve

Figure 18 **Typical pressure gauge with seal pots**



Key

1 Filling and vent valve with removable plug

2 Downward slope towards pot

3 Overflow connection with removable plug – used when filling with seal liquid

4 Pressure transmitter

5 Block and vent valve manifold

6 Lag chamber when used with congealing liquids – heat trace if required

7.2.2.2.3 Pulsation dampeners

Pressure measuring instruments subject to pulsation, e.g. from reciprocating compressors, should be liquid filled or fitted with pulsation dampeners. Snubbers, porous metal discs or needle valves may be used for this purpose.

7.2.2.2.4 Injection cleaning

Impulse lines on high integrity pressure protection systems should be equipped with injection cleaning facilities if the process is prone to material build-up that could adversely affect the detected pressure (subject to suitable chemicals being available and practicable).

The impulse injection facility should not be used to claim a layer of protection without suitable analysis and substantiation, but it may be used to support a reduced function test interval for the protection system.

*COMMENTARY ON **7.2.2.2.4***
Processes which are prone to build-up of matter in impulse lines (such as hydrates) may be equipped with chemical injection facilities, providing a high pressure burst of cleaning fluid (such as methanol) into the impulse line. This has the effect of clearing build-up in the restrictor, however it will cause a temporary high reported pressure from the related pressure sensor.

Multiple voted transmitters on critical applications may use this facility on line by clearing each impulse line separately in time, which provides a high pressure trip test for the transmitters in question without tripping the process. This provides an effective remote test cycle for pressure inputs to high integrity pressure protection systems.

The absence of an injection cleaning facility will result in more periodic manual testing of the protection system, which could reduce process availability.

7.2.2.3 Isolating valves

Pressure measuring instruments should be provided with a process isolating valve and, unless otherwise specified in the original design, a vent valve should be provided between the isolating valve and the pressure instrument to facilitate zero checking and depressurization prior to instrument removal. For some applications, combined isolating and vent manifolds are suitable.

7.2.3 Differential pressure measurement

7.2.3.1 Tapping points

The tapping points should be made in accordance with **7.2.2.1**.

7.2.3.2 Impulse pipework

The impulse pipework arrangement for differential pressure measurement should be the same as for two separate pressure measurements. On no account should a differential pressure gauge be supported by its impulse pipework. It is important that seal chambers, diaphragm seals, condensate pots or filling tees should be at the same level and the impulse pipework should be run together to avoid static pressure errors.

7.2.3.3 Isolating valves

Differential pressure instruments should be provided with a process isolating valve for each connection. Unless otherwise specified in the original design, an equalizing valve should be provided, downstream of the isolating valves, between the two instrument ports to permit zero checking. Vent valves, unless otherwise specified in the original design, for each connection between instrument port and isolating valve should also be provided for depressurisation for maintenance. The isolating, equalizing and vent valves may be incorporated in a single manifold where this conforms to the relevant design specification.

7.2.4 Direct reading instruments

7.2.4.1 Principle

Pressure gauges use the deflection of a bourdon tube, diaphragm, capsule or bellows under pressure to drive a mechanism linked to an indicting pointer on a scale. Low pressure gauges employ U-tube manometers, inclined tube manometers or barometer devices to indicate small gauge pressures or vacuums.

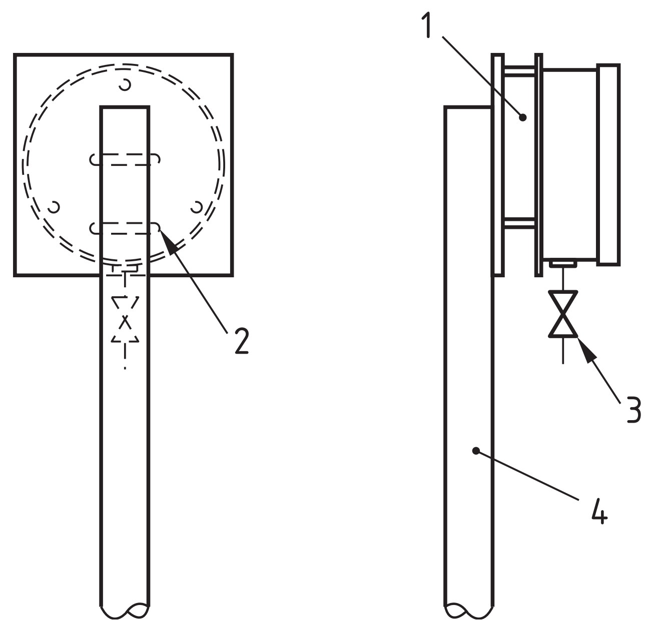
7.2.4.2 Installation

7.2.4.2.1 Location

Indicators should be mounted in a position conveniently accessible and safe for reading.

The gauge may be supported by its piping if it is close coupled to the process connection. Where vibration is expected or where the connection is long, the gauge should be supported independently (see Figure 19).

Figure 19 **Example of independent support for pressure gauges up to 150 mm (6 in) in diameter**



Key

1 Do not obstruct blowout disc – use spacers

2 Welded or "U" bolt

3 Manifold

4 Support tube (not process pipework)

Pressure gauges often incorporate safety blowout devices to relieve excess case pressure in the event of element failure. The blowout back or disc insert should not be obstructed by the gauge support or other structure. There should be clearance of not less than 25 mm between a blowout disc and a nearby obstruction.

Additional protection should be provided as necessary for the specific application, e.g. plastics or safety glass windows and a safety baffle plate between the bourdon tube and the dial (see BS EN 837-1).

7.2.4.2.2 Cleaning and pressure testing

During cleaning and hydraulic pressure testing of the process pipe, the gauges should be isolated and protected from damage by over-pressurization.

7.2.4.2.3 Static head compensation

Gauges on low pressure liquid or condensing vapour service should be compensated for static head by resetting the pointer of the gauge. The value of the compensation applied should be marked on the gauge dial.

7.2.5 Pressure transmitters and switches

7.2.5.1 Principle

The deflection of bourdon tubes or diaphragms under pressure may be used to operate electronic or pneumatic sensing devices and switches.

Transmitters generally incorporate in the same housing the components necessary to convert the sensor signals to a standardized signal output.

7.2.5.2 Installation

7.2.5.2.1 Location

Pressure transmitters and switches should be located as close as possible to the process connection consistent with accessibility for adjustment and servicing. The devices should be mounted in a vibration-free position and should generally be supported independently of the process pipework.

7.2.5.2.2 Electrical connections

Electrical connections to the devices should be in accordance with manufacturer's instructions. Particular care should be taken where strain gauge transducers are employed without integral signal conversion. In this case, multicore cable should be used to connect the transducers to the remote power supply and gauge amplifier, and this should not exceed the length recommended by the manufacturer. This connecting cable should if necessary be routed away from electrical power cabling.

NOTE For installations in hazardous areas, see Clause ***5****.*

7.2.5.2.3 Cleaning and pressure testing

During cleaning of the process pipework and any subsequent hydraulic test, the pressure transmitters and switches should be isolated from the process line and protected from damage by over-pressurization, as impulse lines are often tested to higher pressures than the rating of the instruments.

7.2.5.2.4 Static head transmission

Transmitters or switches on low pressure liquid or condensing vapour service should be compensated for static head when setting up. The value of the compensation should be marked on the equipment.

7.3 Temperature

7.3.1 General

The majority of temperature measuring instruments depend for their correct operation on the positioning and location of the temperature-sensitive portion of the device where the temperature is to be measured. Because of the mechanical difficulties that this requirement can present, a compromise is often necessary in the location of the sensing element.

If head-mounted transmitters for the thermocouple or resistance elements are used, care should be taken to ensure that the device is suitable for the ambient temperature at the point of measurement.

In all cases, the instructions in the manufacturer's literature should be made available to the installation personnel, and any specific warnings noted.

7.3.2 Thermometer sheaths or pockets

Generally, where the temperature measurement of high pressure and/or corrosive fluids is undertaken, the sensing element is protected by a thermowell (mechanical sheath or pocket) that is inserted into the fluid at the point at which the measurement is required. This pocket allows the removal of the sensing device without draining or relieving the pressure of the process fluid, or any other disturbance to the process. The pocket can be constructed in a special material compatible with the process fluid, thus avoiding the need for the temperature sensitive portion of the measuring device to be constructed of non-standard materials.

The thermometer pocket is often installed by the mechanical contractor as part of the pipework or vessel system being constructed. It is essential that a careful check be carried out to ensure that the dimensions of the pocket are correct for the temperature-sensitive device to be installed.

Factors governing selection include:

a) heat exchange area in relation to mass;

b) material of construction, with special emphasis placed on thermal conductivity and corrosion resistance.

The introduction of a pocket adds to the time lag in the response of the instrument to changes in process temperature. Where temperature changes are very slow, this might not be of importance, but where response changes are important, it might be desirable to increase the heat exchange area. This can add to the cost of manufacture, weaken the pocket or make it more susceptible to turbulent fluids.

Where it is considered essential to have a long and comparatively small diameter pocket, its resistance to fracture through turbulence vortex shedding and/or vibration should be taken into account at the design stage.

NOTE Dimensions of temperature detectors and corresponding pockets are specified in BS 2765.

The air space between the thermometer element and its pocket should be kept to a minimum or filled with a heat conducting material. The wall thickness of the pocket should be kept to a minimum compatible with the pressure rating of the system.

If for any reason a device is installed without a pocket, a label should be attached warning of any danger resulting from removal of the instrument.

Non-penetrative techniques, such as clamp-on surface probes, may be used to avoid the need for pockets.

7.3.3 Expansion thermometers

*COMMENTARY ON **7.3.3***
Expansion thermometers utilize the thermal expansion of a metal, liquid or gas to produce a movement proportional to the temperature change to be measured.

Local dial thermometers usually have a bi-metallic or mercury-in-steel sensing element in a stem rigidly attached to the indicating dial. Other instruments, including indicators, controllers and transmitters, employ gas expansion, vapour pressure and mercury-in-steel systems in which the temperature sensing bulb is connected to the measuring element by a length of capillary tubing. Such systems are factory sealed, and capillaries should not be cut.

NOTE Fluid-filled device failures are non-self-revealing, so they are unsuitable for high temperature protection.

Temperature sensors are often delicate devices containing liquids, gases or vapours under pressure. Sensors and any attached capillary tubing should be handled with the utmost care, as often irreparable damage can be inadvertently caused. Where capillary systems are used, they should continuously be supported and protected, and any excess length coiled on a former. Capillaries generally should not be bent to a radius less than 75 mm. Slack should be allowed in the capillary at the insertion point to allow removal of the sensor from the pocket.

In the case of vapour pressure devices, if the bulb is situated at a different level from the bourdon tube, the reading of the thermometer should be suitably compensated for heat errors.

7.3.4 Thermocouples

*COMMENTARY ON **7.3.4***
If a closed circuit is formed from two metals, and the two junctions of the metals are at different temperatures, an electric current will flow round the circuit. The electromotive force (e.m.f.) generated will depend on the materials chosen for the thermocouple and the temperature difference between the two junctions. When the temperature of one junction (reference or cold) is fixed or known, a millivoltmeter connected to the thermocouple can be calibrated to indicate the temperature attained by the measuring junction.

NOTE See BS EN 60584 for details of the relationship between temperature and e.m.f.

The temperature measured will be the result of the net heat supplied to the hot junction by the conventional modes of heat transfer. Factors affecting the measuring junction temperature for a particular installation are as follows:

a) the mass of the thermocouple, together with any insulation material or protective pockets;

b) the thermal conductivity of the materials chosen for the thermocouple and any protection pockets;

c) ratio of heat transfer areas of the thermocouple and the body of which the temperature is to be measured;

d) temperatures of the immediate surrounding areas;

e) emissivity of the exposed surfaces;

f) velocity;

g) properties of the medium whose temperature is to be measured.

7.3.4.1 Extension wire/compensating cable

In order to compensate the instrument reading for cold junction temperature changes, the cold junction is often extended to the instrument. For base metal thermocouples, extension wires generally use the same materials as the thermocouple. For high temperature applications, materials used for the manufacture of the thermocouples may be chosen from the precious (noble) metals. However, the cost of using these materials as extension leads would normally be prohibitive. The problem can be overcome by using compensating leads, which, although their conductors are of different materials, have a similar thermoelectric characteristic to that of the thermocouple. This can also apply when materials other than noble metals are used.

When compensating leads are used, care should be taken to ensure that the temperature at the termination between the thermocouple and the compensating leads does not become too high. Compensating leads have similar characteristics to thermocouple wires for the limited range of ambient temperature specified by the manufacturer, usually between 0 °C and 100 °C. The compensation will not be accurate if the actual temperature of the leads exceeds the figures specified by the manufacturer.

7.3.4.2 Installation

7.3.4.2.1 General

*NOTE For further information on cable installation, jointing and segregation, see Clause **15**.*

Wherever possible, the use of connecting termination housing is recommended to ensure a positive connection between the thermometer element and connecting wires. It should be ensured that:

a) all connections are tight;

b) covers are securely fixed;

c) all gaskets are correctly located and in good condition.

The materials and construction of the connecting termination housing should be chosen with regard to the environmental conditions that apply. Particular care should be taken to ensure that any weatherproofing gaskets are correctly located.

The installation should be carried out such that the thermocouple can be easily removed for renewal and its method of securing should be such that, when removing it, the possibility of securing devices, which contribute to the plant integrity, being loosened inadvertently is minimized.

Mineral insulated thermocouples should be checked to ensure that they are of the specified type and length for the application. Any spare length should be coiled and supported near to the termination. They should not be cut to length, unless specific instructions are given. Sealing ends should be handled in accordance with the manufacturer's instructions.

It is essential that compensation cables are installed with the correct polarity. Colour coded insulation is often employed and the cable manufacturer's literature should be consulted. When this is not possible, the following information can be used to determine polarity in the field.

1) Cables manufactured in accordance with BS EN 60584-3 have the negative conductor insulation coloured blue.

2) For nickel chromium (chromel)/copper nickel (constantan) thermocouples (type E), the negative conductor is silver in appearance. It has a lower resistance in Ω/km than the positive conductor for the same wire size.

3) For iron/copper nickel (constantan) thermocouples (type J), the positive conductor is often rusty in appearance and is magnetic. It has a lower resistance in Ω/km than the positive conductor for the same wire size.

4) For nickel chromium/nickel aluminium thermocouples (type K), the negative conductor is slightly magnetic. It has a lower resistance in Ω/km than the positive conductor for the same wire size.

5) For platinum-rhodium/platinum thermocouples (type R or S), the negative conductor is softer than the positive conductor. It has a lower resistance in Ω/km than the positive conductor for the same wire size.

6) For copper/copper nickel (constantan) thermocouples (type T), the positive conductor insulation is red in appearance. The negative conductor has a lower resistance in Ω/km than the positive conductor for the same wire size.

Bottoming of the thermocouple in a thermowell or pocket is often practised to improve the response to temperature change. Bottoming consists of having the thermocouple junction pressed tightly against the end or bottom of the thermopocket. In the case of sheathed thermocouples the bottoming is achieved by spring loading.

Care should be taken in the case of intrinsically safe installations to ensure that the earthing requirements of the thermocouple are not invalidated.

Thermocouple extension wires and compensating cables should always be installed in such a way as to protect them from excessive heat, moisture and mechanical damage. Compensation cables, other than armoured multicores, should be protected by conduit or trunking, so that they are not subjected to excessive flexing or bending which might change the thermoelectric characteristics.

Non-integral cold junction devices should be mounted in accordance with the manufacturer's recommendations and with due regard to ambient conditions. The location of the cold junction device should be agreed with the responsible engineer. Subject to the approval of the responsible engineer, cabling from the cold junction device to the temperature indicator or recorder should be run in twisted pair, screened copper conductors.

Where possible, the layout and arrangement of conduits or trunking for a thermocouple system should include long radius bends instead of elbows, since cold working of extension wire materials can introduce inhomogeneity and pulling the extension wire through a number of elbows could work the wires unnecessarily.

The length of extension wire should be kept as short as possible, and where possible the wire from the thermocouple connection head to the instrument terminal or reference junction should be in one continuous length. Where splices are unavoidable, they should be made by compressing the two wires to be joined to obtain intimate wire-to-wire metallic contact with a compression device, preferably of the same or compatible material. When any connections are made, polarity should be strictly observed.

7.3.4.2.2 Installation in hazardous environments

When thermocouples are installed in hazardous areas, any apparatus connected to the thermocouples should conform to the system certification requirements. The certificate should be inspected by the installing engineer to ensure conformity to any specific installation requirements (see Clause **5**).

7.3.4.2.3 Thermocouple indication

Instruments connected to thermocouples should be housed in suitable environments, depending on their type.

When the instrument incorporates automatic cold junction temperature compensation, care should be taken to ensure that the ambient temperatures encountered are within the range of compensation specified by the manufacturer.

7.3.5 Resistance thermometers

*COMMENTARY ON **7.3.5***
Pure metallic conductors increase their electrical resistance with increase in temperature, and this property is used as a basis for the measurement of temperature over a wide range. In practical thermometry, the metals used for the construction of resistance elements are platinum, nickel and copper because they can be manufactured to a high degree of purity, and have a high degree of reproducibility of temperature/resistance characteristics.

*As with other thermometers, the temperature measured will be the result of the net heat supplied to the element. The factors that are applicable are the same as those outlined in the commentary on **7.3.4** for thermocouples.*

7.3.5.1 Connecting cabling/wiring

Connecting cables between resistance elements and read-out instruments employ standard copper conductors. The device that is to be connected to the resistance element dictates the method (if any) to be used to compensate for the resistance of the connecting cables between the thermometer element and the remote instrument.

In the simplest installations, a ballast resistor should be adjusted in the circuit to bring the total resistance of the element, leads and make-up resistance to some standard value.

In other systems, additional conductors are run between the thermometer head and the remote instrument to compensate for the lead resistances, and any changes within them that take place due to temperature changes along the transmission route. The method of connection and identification of leads should be in accordance with BS EN 60751. In all cases, the instrument manufacturer's instructions should be followed.

7.3.5.2 Installation

7.3.5.2.1 Resistance element

The location and use of pockets for resistance elements are similar to those outlined for thermocouples.

However, the construction of the resistance thermometer element makes it more susceptible to damage from vibration than the thermocouple, and care should be taken to ensure the element is not subjected to vibration outside the manufacturer's specification.

On thermometers incorporating rigid sheaths, particular care should be taken to ensure that these are not bent, as irreparable damage can be caused to the internal element conductors.

7.3.5.2.2 Interconnecting cables

*NOTE For further information see Clause **15**.*

All cores connected to a resistance thermometer should be of the same material and size. It is recommended that they are part of a single multicore cable.

7.3.5.2.3 Installation in hazardous environments

As with thermocouple installations, the cabling should conform to any certification requirements for use in potentially explosive atmospheres. The certificate should be inspected by the installing engineer to ensure conformity to any specific installation requirements (see Clause **5**).

7.3.6 Total radiation pyrometers

*COMMENTARY ON **7.3.6***
Temperature measurements utilizing infra-red radiation techniques are particularly useful in applications above 1 400 °C. They are also useful for measuring lower temperatures of objects that are inaccessible to other forms of thermometer, as they do not need to be in contact with the object of which the temperature is to be measured.

In the total radiation pyrometer, the radiation emitted by the body whose temperature is required is focused on a suitable type of thermal element, the output of which is proportional to the temperature.

7.3.6.1 Installation

It is essential that the installation requirements of the manufacturer are fully understood by the installing engineer, as the success of the measurement will depend on their correct application.

The indication of the pyrometer should be independent over a considerable range of the distance of the source; however, the distances between source and sensor should be checked to ensure that the focus and cone of sensitivity conform to the manufacturer's specification.

Where a refractory tube is inserted through a furnace wall, it should protrude into the furnace a distance between two and five tube diameters depending on the tube material.

7.3.6.2 Filters

Particular types of flame, or the presence of particular flue gases, might require the use of special lenses or filters. In difficult applications, a sighting tube purged by dry air or nitrogen may be used.

7.3.7 Optical pyrometers

Optical pyrometers should not be used for recording or controlling temperatures, but they provide an accurate method of measuring temperatures of up to 3 000 °C and are particularly useful for checking and calibrating total radiation thermometers.

The majority of optical systems are portable and as such do not require any installation. However, their use can involve the selection of particular filters, and the careful setting of adjustments. It is essential that the manufacturer's instructions are followed.

7.3.8 Photoelectric pyrometers

To overcome the necessity for the use of a skilled operator with the optical pyrometer, measurements of radiation at shorter wavelengths can be achieved by the use of photoelectric cells. These devices are often used for the measurement of small objects at high temperature, e.g. the temperature of an object 25 mm in diameter, at 2 000 °C, can be accurately measured with a detector 3 m from the source.

7.3.9 Ratio pyrometers

*COMMENTARY ON **7.3.9***
This type of device has been developed principally to reduce the emissivity error in surface temperature measurement, by measuring the ratio of radiation intensities at two wavelengths.

The installation of photoelectric and ratio pyrometers should be carried out in a similar manner to that for total radiation pyrometers (see **7.3.6**).

7.3.10 Fibre optic temperature measurement systems

The installation of fibre optic temperature measurement systems should be in accordance with **7.10**.

7.4 Level

*COMMENTARY ON **7.4***
There are many types of level measuring devices and these can be generally classed in three groups.

In the first group, level is measured directly by such means as dip-sticks, sight glasses or float-actuated mechanisms.

The second group operates on the general principle that the pressure exerted at the bottom of the tank or vessel depends only on the depth and density of the liquid. (In the case of a closed tank or vessel, account should be taken of the air or vapour pressure acting upon the liquid.) If, therefore, the density remains constant, the depth (or level) is directly related to the pressure. This would include devices such as dip tube and differential pressure instruments.

The third group covers electrical/electronic methods (such as capacitance probes), ultrasonic, nucleonic, load cell, electrical conductivity and optical methods, etc.

Typical level instrumentation includes:

- *transmitter type:*
  - *differential pressure (DP);*
  - *pressure;*
  - *radar (guided wave);*
  - *magneto restrictive;*
  - *displacer;*
  - *ultrasonic;*
  - *RF admittance;*
  - *RF capacitance;*
  - *servo tank gauge;*

  - *radar open (cone/horn);*
  - *hydrostatic (mass/level/density measurement);*
  - *nucleonic;*
- *indicator type:*
  - *magnetic (float/flapper);*
  - *glass (reflex/transparent);*
  - *tank gauge (tape/wire type);*
- *switch type:*
  - *float/displacer;*
  - *capacitance;*
  - *ultrasonic;*
  - *RF admittance;*
  - *RF capacitance;*
  - *vibrating fork;*
  - *conductivity;*
  - *rotating paddle;*
  - *thermal level;*
  - *nucleonic.*

7.4.1 Gauge glasses

Gauge glasses are normally fitted directly to screwed bosses or flanged nozzles on the vessel but may occasionally be connected by pipes where other equipment might obscure observation and prevent access if the gauge is directly fitted. In all cases the branch connections should be finalized at the design stage, but care should be taken during installation to ensure that there is good visibility and also that the gauge glass is mounted vertically and is not subject to any strain. This also applies to magnetic gauge glasses, or level interface indicators.

When gauge glasses are used in conjunction with a level measuring device, both may be mounted on a standpipe, thus reducing the number of connections required on the vessel (see Figure 20).

Gauge glasses for boiler applications should conform to BS 759-1.

When gauge glasses are used, they should be protected against mechanical damage.

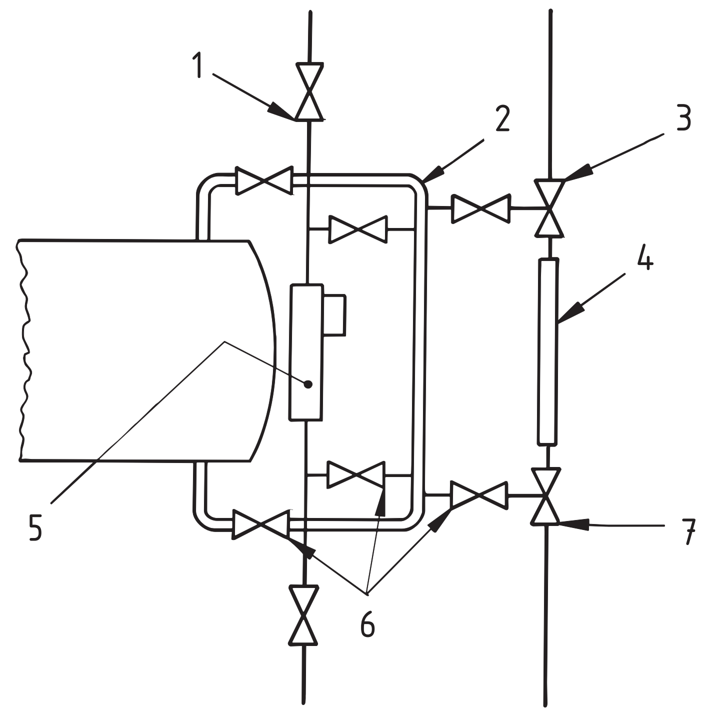
7.4.2 Float switches

Float switches operate by the physical movement of a float being transmitted directly via a gland or indirectly via a magnetic coupling to an electrical pneumatic switch. These are usually mounted in an external float chamber, but the float may be directly mounted through the vessel wall where choking of extended connections is liable to occur.

The branch or pad onto which the switch is fitted should be specified at the original design stage, but the position should be checked to ensure that there is adequate clearance for fitting, that it is possible to remove it for maintenance purposes, and that there is freedom of movement to allow correct operation.

Float switches for boiler applications should conform to BS 759-1.

Figure 20 **Example of level measurement on a vessel using a standpipe**



Key

1 Test/filling (and below drain valves), if required
2 Standpipe 50 mm or larger
3 Automatic blowout lock valve and vent valve
4 Gauge glass
5 Buoyancy transducer
6 Isolating valves
7 Automatic blowout lock valve and drain valve

7.4.3 Buoyancy devices

Buoyancy devices operate by transmitting the change in buoyancy of a float as its immersion varies. In general buoyancy devices should be fitted in the same way as float switches (see **7.4.2**).

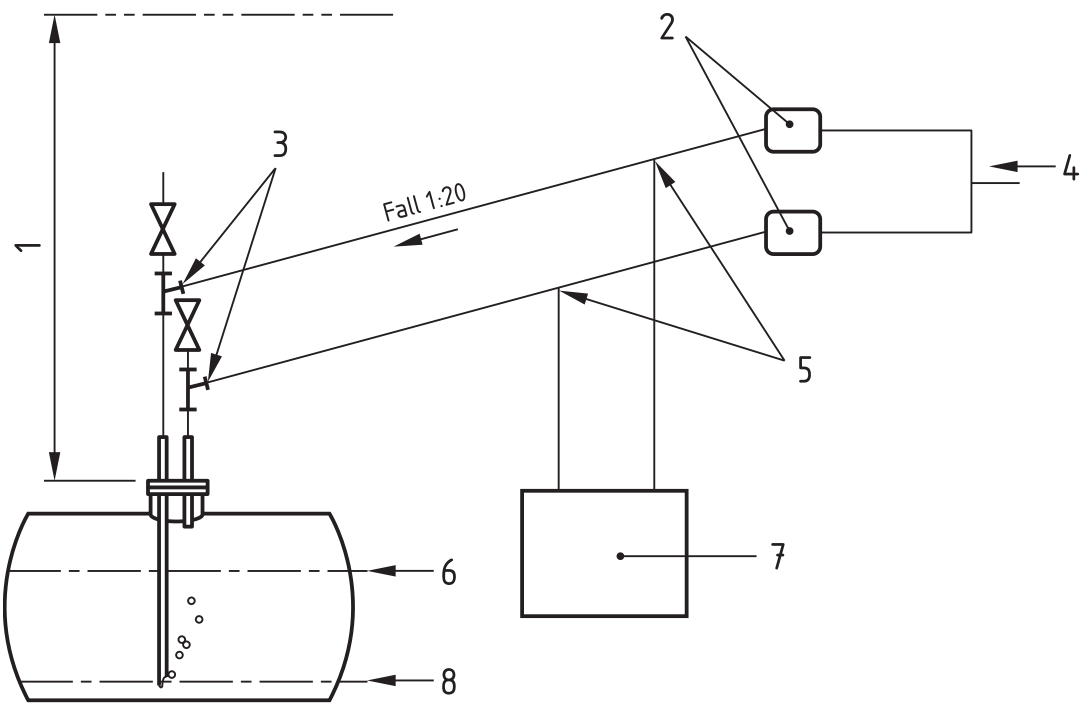
7.4.4 Dip tubes

Dip tubes operate by passing a constant flow of air or other suitable gas through a dip tube in the vessel.

The pressure (or differential pressure in the case of sealed vessels) required to maintain the constant flow can be directly related to the level and indicated directly on a manometer or differential pressure gauge or transmitted via a differential pressure cell. Adequate clearance for fitting and removing the dip pipe is essential.

In applications where sedimentation is likely to occur in the bottom of the vessel, the dip tube should be positioned such that sediment does not obstruct air flow (see Figure 21).

Figure 21 **Example of level measurement using purged dip tube**



Key

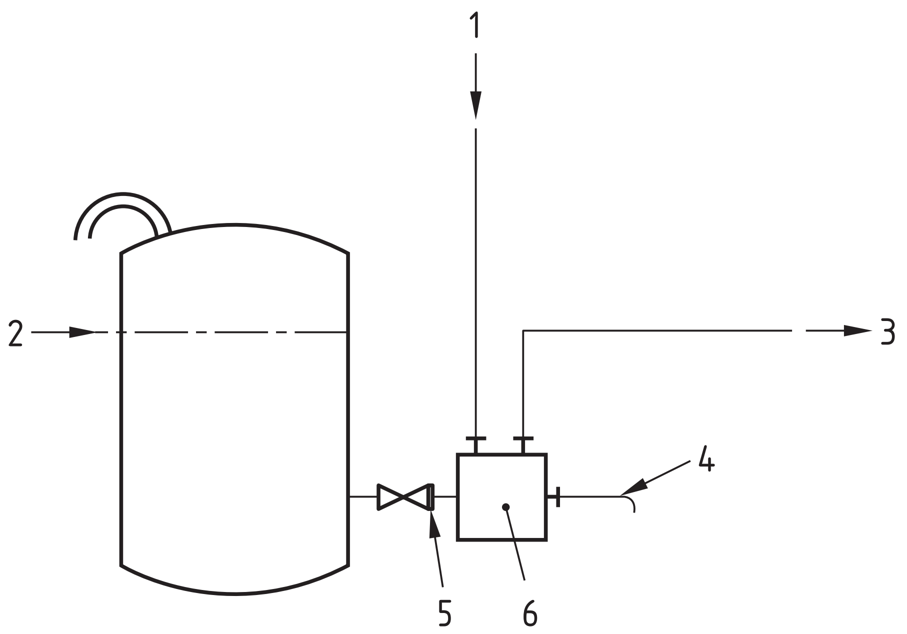
1 Dip tube removal clearance
2 Constant flow devices
3 Tees for rodding purposes
4 Air or other specified operating gas
5 Positioned as near to tank as possible
6 Liquid level
7 Differential pressure transmitter and isolating manifold
8 Level gauge zero

7.4.5 Differential pressure devices

Differential pressure devices operate by measuring the hydrostatic head at a branch situated near the bottom of the vessel and transmitting the signal either electronically or pneumatically by a differential pressure cell (see Figure 22).

Where the vessel is pressurized, a more complicated system of connections to the differential pressure cell is necessary, depending upon the physical properties of the liquid. If the liquid is not volatile under any operating or ambient condition, the basic arrangement shown in Figure 23 may be employed. If it is volatile at ambient temperatures, precautions should be taken to prevent condensation of the liquid in the balance line, resulting in serious errors in measurement. The balance line may be heat traced or a catch pot may be added to the arrangement shown in Figure 23.

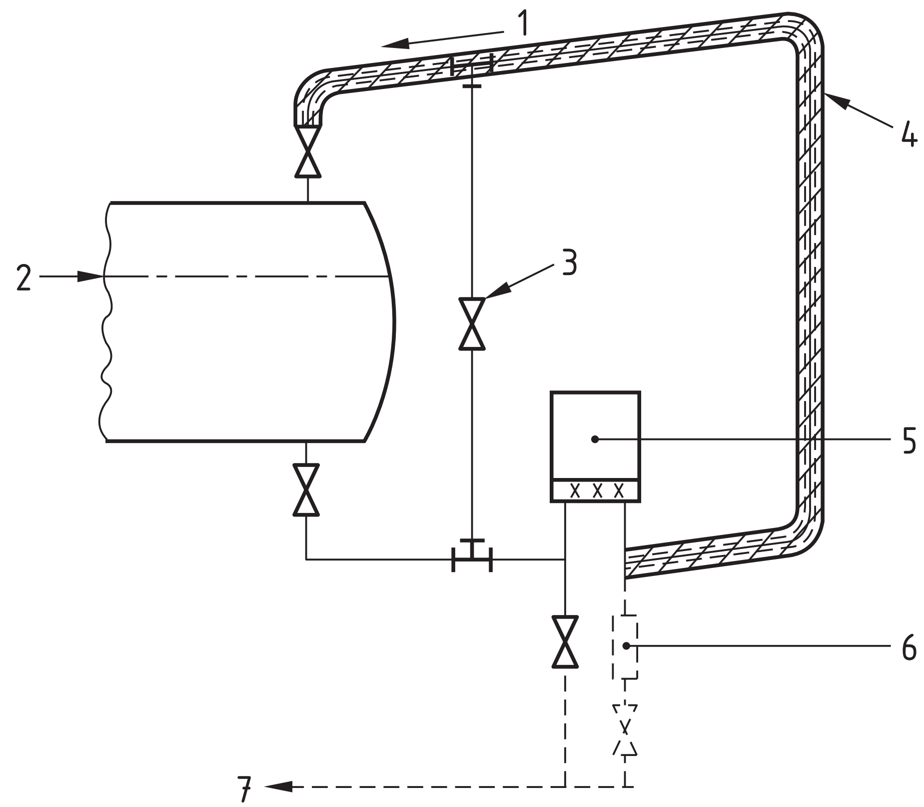
Figure 22 **Example of level measurement using differential pressure transmitter on vented tank**



Key

1 Supply
2 Liquid level
3 Output
4 Low-pressure connection (open to atmosphere)
5 High-pressure connection
6 Differential pressure transmitter

Figure 23 **Example of differential pressure level measurement on a pressurized vessel**

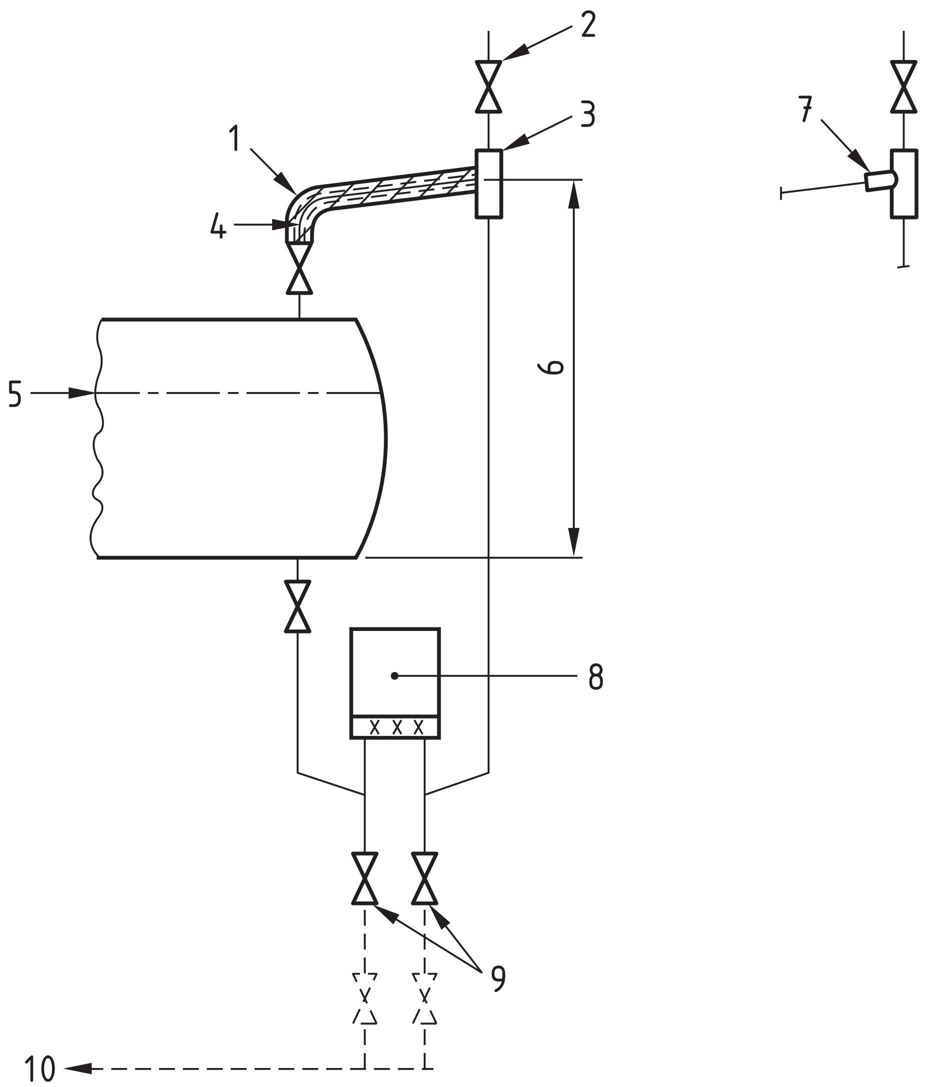


Key

1 Downward slope
2 Liquid level
3 Equalizing valve if required
4 Line and balance connection to be heat-traced and thermally insulated if required
5 Differential pressure transmitter and isolating manifold
6 Catch pot included for volatile liquids if required
7 To drain

For liquids close to saturation conditions, or in any other situation if specified in the original design drawing, a “wet leg” may be used to ensure that the balance retains a constant head of fluid; however, the zero of the instrument should be suitably suppressed (see Figure 24).

Figure 24 **Example of differential pressure level measurement on a vessel containing a liquid near saturation conditions**



Key

1 Line and balance connection to be heat-traced and insulated if required
2 Vent/filling valve
3 Condensate pot (not insulated)
4 12 mm minimum tapping and line size
5 Liquid level
6 Height as specified
7 35 mm filling tee alternative to condensate pot if required
8 Differential pressure transmitter and isolating manifold
9 Blowdown valves
10 To drain

7.4.6 Capacitive measuring method

7.4.6.1 Principle

This method depends for its operation on the variation in capacitance between two electrodes which occur when the dielectric between the electrodes varies due to level changes.

Process media to be monitored in this way can be classified as either insulating materials or electrolytes (as in the case of water). The relative dielectric constant is the factor by which the electrical field strength in the appropriate medium is greater than the field strength in a vacuum.

There is a wide range of probe types available, and care should be taken in matching the probe to the process medium involved and physical application.

7.4.6.2 Installation arrangement

Generally, the self-contained nature of the probe makes it especially suitable for simple and practical installation, the power supply and output signal being the only connections necessary.

Care should be taken in positioning probes to ensure that they do not foul the path of incoming or outgoing process media. Output signal cables should be segregated to induced electrical interference from the power supply cables.

7.4.7 Ultrasonic method

7.4.7.1 Principle

An ultrasonic pulse is transmitted by a transducer and this is reflected from the surface of the material in the container back to the transducer, which converts the ultrasonic energy in the pulse to an electrical signal. The transducer therefore acts first as a transmitter and then as a receiver.

The applications that generally favour the ultrasonic method are those where contact with the process medium would be undesirable. If foam is present on the surface of the liquid to be measured, then better results can often be obtained at longer wavelengths, i.e. below 25 kHz.

Where fluctuations in temperature occur, it might be necessary to fit a temperature compensation probe.

Ultrasonic devices are also available operating in the "bottom-up mode", i.e. with the transducer mounted at the bottom of the vessel. An echo from the liquid surface is received and the time of flight measured. This application is ideally suited to clear liquids.

7.4.7.2 Installation arrangement

Installation of these devices is relatively simple with the fixing generally being of the flange type, but care should be taken to ensure that the face of the sensor is completely clear.

7.4.8 Nucleonic level measurement

7.4.8.1 General

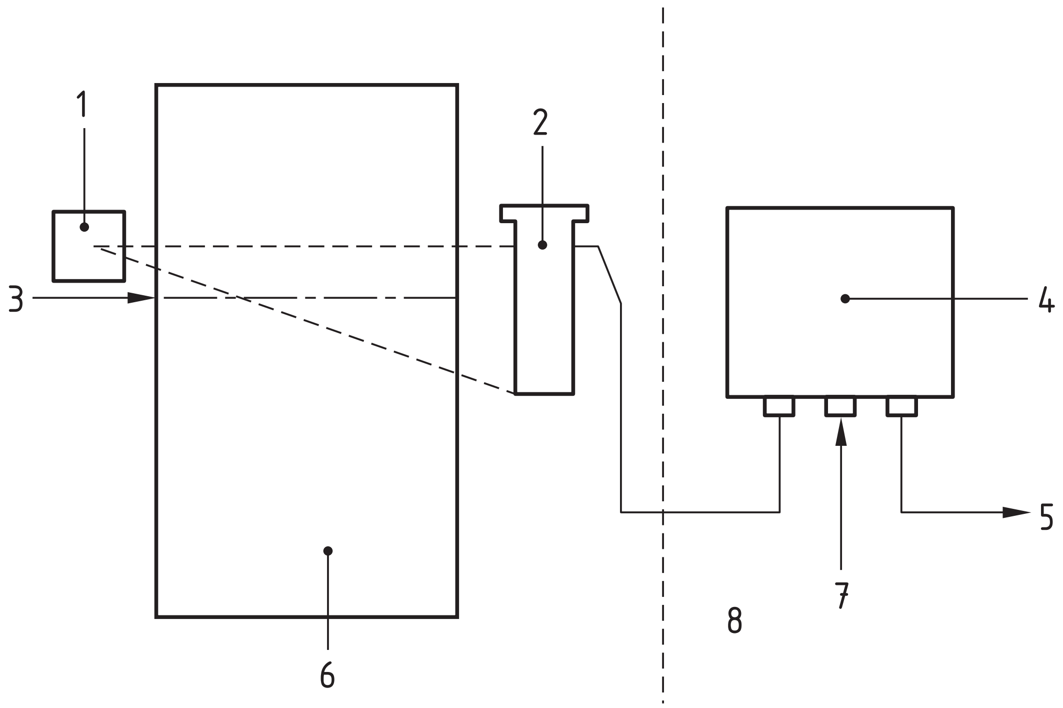
NOTE See Figure 25 for an example of an installation arrangement.

Nucleonic level measurement systems are based on the absorption of gamma rays. The amount of absorption for a given material is a function of the density and path lengths through the material. In this method a radioactive source is positioned to direct a beam of gamma rays through the tank or vessel to a detector mounted on the opposite side. As the level of the material rises it attenuates the radiation over an increasing length of the detector, the output signal of which is proportional to the level.

Applications are generally confined to the measurement of level in tanks or vessels operating under difficult conditions, e.g. high pressure, corrosive or abrasive media and high temperature.

When nucleonic level measurement is used, it is essential that the radiation source is appropriately determined for the size and type of vessel.

Figure 25 **Example of nucleonic level measurement**



Key

1 Radioactive source in shielded container with lockable shutter
2 Detector unit
3 Liquid level
4 Control unit
5 Output signal
6 Tank/vessel
7 Power supply
8 Equipment room

7.4.8.2 Installation

When installing a gamma radiation source and detector:

*NOTE Attention is drawn to health regulations in respect of radioactive sources (see **4.16**).*

a) the safety recommendations given in **4.16** should be met;

b) access should be provided to enable regular inspections of the source to be made;

c) it is essential to check that the strength of the gamma source is correct for the particular application and that the commissioning stage adjustments are made to offset the absorption due to the density of the vessel wall material;

d) the source and detector should be aligned such that the path between them is uninterrupted by any moving parts, e.g. stirrers.

7.4.9 Load cell measuring method

7.4.9.1 Principle

An indirect method of determining level is by measuring the mass of a vessel and its contents by means of one or more load cells placed under the vessel support structure. Several types of load cells are available, e.g. volumetric type and the electronic strain gauge type. One to four elements can be used, depending on the supporting system of the vessel and the accuracy required. The relationship between mass and level will depend on the geometry of the vessel (see **7.7**).

7.4.9.2 Installation arrangement

Installation of the load cells is generally carried out by the mechanical contractor but vessels should be freely supported and care taken to ensure that any connecting pipework does not impose any extraneous forces (e.g. from expansion) on the vessel, as these can cause errors in the measurement.

7.4.10 Electrical conductivity measuring method

7.4.10.1 Principle

This type of measurement can operate only with electrolyte solutions such as water. An electrode on insulated mountings is inserted in the metallic tank. An a.c. voltage is applied between the electrode and the wall of the tank.

When the process medium touches the electrode, a current flows between the electrode and the tank wall and the output of the sensor switches. An a.c. voltage is used to prevent electrolysis at the electrode. High and low level switching can be achieved using two electrodes, the limits being determined by the lengths of the probes.

7.4.10.2 Installation arrangement

Generally the self-contained nature of the probe(s) make it especially suitable for single practical installation. If the tank is not metal, a further electrode, which should be longer than any of the other electrodes, should be used to earth the liquid.

7.4.11 Automatic level gauging

7.4.11.1 Principle

The electrically powered servo-operated gauge has a surface sensor as the detecting element which follows variations in level by means of a servo-mechanism. Electrical power provides both gauge operation and remote transmission.

Mechanically operated types are also in use with the detecting element, which is normally a float, providing sufficient power directly to drive a transmitter.

7.4.11.2 Installation arrangement

The gauge should be mounted on either the lower part of the tank shell or by the preferred method of a support pipe, but this will be dependent on the type of gauge and whether the tank has a fixed-roof or a floating roof.

After the tank has been hydrostatically tested, a check should be carried out to ensure that the support pipe is plumb and the guide wires are in their correct position, prior to any adjustment.

7.5 Mechanical measurements

7.5.1 Position

7.5.1.1 Principle

Linear and angular position measurements employ one of five classes of device:

a) magnetic devices, e.g. linear variable differential transformers;

b) synchro devices and proximity switches;

c) electrical devices, e.g. potentiometers and limit switches;

d) optical devices, e.g. interrupted beam sensors, digital lasers;

e) pneumatic devices.

Continuous measuring devices are generally of similar appearance for their application, i.e. linear or angular. Position switches have arrangements dependent on whether they are contact or non-contact types.

Although there is a wide range of position measurement and sensing devices, the installation procedure is similar.

7.5.1.2 Installation

7.5.1.2.1 Location

Position-sensing devices should, where possible, be mounted remote from sources of heating or leakage of process, gases or liquids.

To obtain the best performance, position sensors should be placed in a vibration-free location. Where vibration cannot be avoided, it is desirable to provide flexibility in the coupling of the device to the point of measurement and in the transducer mountings.

7.5.1.2.2 Mounting

Devices should be mounted only after the mechanical assembly of other parts is complete.

7.5.1.2.3 Alignment

Alignment of contact measuring devices with the moving point should be arranged and adjusted to avoid stress due to movement in directions other than the direction of interest. Flexible joints, elastic or spring couplings or ball joints can be used to avoid such stresses.

Slack linkage joints should not be used to obtain flexibility; all joints should be tightened to avoid slackness while permitting free movement.

Non-contact devices should be arranged so that clearance between the device and the detected point is not subject to large variations as parts wear. The clearance should be set up in accordance with the manufacturer's instructions.

Interrupted beam devices should be arranged and adjusted to avoid contact between the moving part and the emitter or detector elements.

7.5.1.2.4 Travel

The sensing device should be arranged so that any overtravel due to wear or fault will not damage the device.

Adjustable linkages or cams should be set to give correct operation over the normal range of travel and to avoid damage in case of overtravel.

7.5.1.2.5 Electrical connections

The electrical arrangement should be in accordance with the manufacturer's instructions. Flexible wiring to transducers should be supported and protected so that it is neither trapped, drawn tight nor bent too tightly by moving parts.

7.5.2 Speed

7.5.2.1 Principle

The various types of speed transducers employ different principles of operation.

The drag cup indicator employs the eddy current drag of a rotating magnet on a sprung conducting cup or disc to indicate speed.

Tachogenerators generate an output voltage (d.c. or a.c.) proportional to speed.

Speed may be measured by counting electrical pulses induced in a magnetic probe close to moving teeth or slots on a shaft.

Pulses of light or infra-red radiation reflected from or interrupted by markings or teeth on a shaft may be counted to measure the speed by using optical devices.

Devices employing these different methods of measurements form two groups, contact and non-contact devices, which have different installation procedures.

7.5.2.2 Installation

7.5.2.2.1 Mounting

Devices should be installed only after mechanical assembly of related parts is complete.

7.5.2.2.2 Contact transducer alignment

The transducer should be mounted such that misalignment and vibration do not affect reliable operation.

Where vibrations or adverse environmental conditions are a problem, transducers or speed indicators can be mounted a limited distance from the point of measurement by using a flexible Bowden cable drive. Such a flexible drive should be supported and routed to avoid excessive bending of the cable.

Where the transducer is coupled directly, flexible couplings should be used to minimize problems due to misalignment. The transducer mounting should be positioned to permit close coupling to the moving parts so that the relative motion between the mounting and point of measurement is minimized. Alignment should be adjusted to minimize flexing of couplings.

In some types of transducers, the tachometer rotor is fixed rigidly to the end of a motor or drive shaft and has no separate bearings.

7.5.2.2.3 Non-contact transducer alignment

Non-contact transducers should be mounted so that they retain a fixed relationship to the moving parts. It is preferable to mount the transducer adjacent to bearings unless the device design is tolerant of misalignment.

Magnetic induction probes should be aligned to maintain the specified clearance from the tooth or shaft surface. It is advisable to check that the clearance is correct with the shaft in different angular positions.

Optical transducer alignment should be in accordance with the manufacturer's instructions.

7.5.3 Vibration and acceleration

7.5.3.1 Principle

Vibration is measured either by position velocity or acceleration transducers.

Non-contact position transducers are used for lower frequency vibration measurement and should be installed as described in **7.5.1**. Position transducers are an integral part of absolute vibration transducers which measure shaft vibration, the output being corrected for vibration of the transducer mounting.

Velocity transducers for vibration measurement sense the relative velocity of a suspended mass and the transducer casing. Relative movement between the mass and the transducer magnetic circuit induces voltages in the output coil proportional to vibration velocity.

Acceleration transducers measure vibration forces on a mass within the transducer using either piezo-electric or strain gauge elements.

The vibration transducer may incorporate an integral signal conditioning or charge amplifier to generate a low impedance output signal, or the amplifier may be mounted separately.

7.5.3.2 Installation

7.5.3.2.1 Location

Vibration transducers for machinery monitoring are normally mounted on the bearing housings either in the vertical or horizontal plane. For special applications, other mounting locations may be specified in the original design.

Vibration transducers should be protected against environmental and mechanical hazards, preferably by means of a protective enclosure.

7.5.3.2.2 Mounting

For correct operation, vibration transducers should be closely coupled to the machine component of interest. It is recommended that, wherever possible, integral bosses be provided for mounting vibration transducers.

Vibration transducers that are mounted by means of a stud or clamp should be fixed to a mounting plate having a very low surface roughness to ensure rigidity of coupling. Mounting plates should be fixed by a suitable method to the prepared surface of the mounting boss or bearing housing.

For all aspects of mounting arrangement and practice, it is important that the manufacturer's instructions are followed.

7.5.3.2.3 Electrical connections

The output signals generated by accelerometers and position transducers without integral signal conversion amplifiers are often of high impedance and need to be shielded from interference to avoid measurement errors. Manufacturer's standard cableforms with ready-made terminations should be used as far as possible for connecting the transducers to external amplifiers.

Flexible cables from transducers should be protected from mechanical and environmental damage by the use of flexible or rigid conduit appropriate to the application.

Where these conduits pass from a hazardous area to a safe area, the cable should pass through a gas-tight seal. To avoid damage when screwing the transducer into its mounting plate, flexible cables should not be connected until the transducer has been fixed and fully tightened.

7.6 Weighing machines

*COMMENTARY ON **7.6***
Industrial weighing machines fall into three categories: portable, dormant (mechanical, load cell and gyroscopic) and special application.

Where machines are used for weighing for sale or excise duty, it is a statutory requirement to have them passed by a Weights and Measures Inspector. Because of their size and apparent robustness it is not always appreciated that weighing machines are very sensitive to mechanical shock, but with careful treatment, accuracies of 0.02% are achieved and can be maintained over a temperature range from –10 °C to +40 °C.

7.6.1 Portable machines

Portable machines are normally supplied as a complete unit, and should be levelled only when placed in their final position.

7.6.2 Dormant machines (mechanical)

The bottom work for mechanical dormant machines should be permanently fixed in concrete flooring or plant steelwork. Detailed drawings of the mounting should be provided and all necessary concrete plinths, fixing brackets for knife edge supports and transfer levers should be carefully checked dimensionally before the machine is installed. The installation should be carried out by the manufacturer's engineers or at least supervised by them; however, the installation contractor may be called upon to supply unskilled labour, particularly with large machines. Where machines are installed in the open, e.g. road or rail weighbridges, or in plant areas likely to be sluiced down or where spillages are anticipated, special features will have been designed in the bases to ensure adequate drainage. Such features should be carefully checked before machine assembly commences.

The indicating or recording portion normally referred to as the headwork can take a variety of forms. Headworks mounted directly on the bottom work present no problems, but if the indicator is remote, e.g. one floor above, the lever movement may be transmitted via a steel rod; it is essential in such cases that the headwork is fastened to supports so designed that there is no movement of the headwork relative to the bottom work. Where the movement is transmitted electrically, then the relevant recommendations given in Clause **15** should be followed.

The manufacturer's engineer is ultimately responsible for accurate operation but careful checking by the installation contractor can avoid delays. If a tank is fitted on to the machine and is connected by pipes to other process equipment, such piping arrangements should be carefully considered at the design stage and the equipment should be supplied in accordance with the design specification. It is important to ensure that when the pipe joints are made there is no strain transmitted to the bottom work. All such pipework should be carefully fitted. It is essential that the manufacturer's engineer is present when all pipe connections are made.

7.6.3 Dormant machines (load cell type)

Dormant machines of the load cell type utilize strain gauges at the loading points and generally require much shallower and less complicated concrete foundations.

Nevertheless all concrete or steelwork supports should be carefully checked dimensionally before machine installation. As there is virtually no movement in the bottom work portion, with the exception of large weighbridges, and as all indication is transmitted electronically, most of the recommendations for mechanical machines do not apply. Full instructions for cable connections, etc., are expect to be provided by the manufacturer, but the relevant recommendations given in Clause **15** should also be followed. The manufacturer's engineer is responsible for the completed installation but liaison will be necessary. Many load cell machines carrying vessels that are subject to lateral forces, e.g. stirred vessels on large hoppers in windy situations, should have an appropriate design of restraining system. These should be carefully fitted in accordance with the design requirements.

All load cells should be upright and rigidly mounted.

It is most important when welding is performed adjacent to load cells that the cells are kept well protected, and on no account should the load cell be used as an earth as they can be easily damaged electrically. Where load cells are mounted in hazardous areas they should be certified as being suitable for such use. Alternatively, the circuit might have been designed using barrier units, but these reduce the accuracy of the system.

Most load cell weighing systems are supplied complete by specialist manufacturers. In the event of a system being designed by a non-specialist, who obtains the load cells and indictors from different manufacturers, it is essential to ensure that the load cells and indicators are compatible electrically.

7.6.4 Dormant machines (pneumatic)

Pneumatic dormant machine installations are almost always designed for specific installations, and the manufacturer's installation instructions should be followed.

7.6.5 Single-ended machines

Single-ended machines are used on horizontal tanks with a fulcrum at one end of the tank and the weighing arrangement (load cell or mechanical) at the other. Such machines should be used only on liquid, and calibration should be checked only by adding known quantities of liquid and by using an accurate integrating flowmeter or a calibration tank.

7.6.6 Belt weighers

*COMMENTARY ON **7.6.6***
There are a variety of types of belt weighers, based on different principles, e.g. electronic, pneumatic, hydraulic, mechanical and nucleonic.

*There are several nucleonic weighers on the market. It is essential that specialised advice is sought from the Radiation Protection Adviser about the precautions that have to be taken to protect personnel from radiation. This is especially important when the quantity of radioactive isotopes used is relatively large (see Clause **4**).*

However, all comprise four basic elements: a weigh length element, a force sensing element, a tachometer or odometer and a computing element which computes the weight from the force exerted by the load on the belt for a fixed weigh length at whatever speed the belt is travelling.

Weighers should be fitted in belts that are correctly tensioned (this usually necessitates an automatic tension device), correctly aligned and without non-vulcanized joints. Particular care should be taken to avoid imperfect or misaligned idlers, and structural deformation of the belt supports should also be avoided.

Spillage from, or dirt adhering to, the belt can cause serious inaccuracies to occur and the installation should provide means to prevent this happening.

The effect of wind on long exposed belts is expected to have been considered at the design stage. The choice of location for the installation should take account of the possibility of wind effects on long exposed belts.

Calibration of belt weighers can be carried out in a number of ways, e.g. with check weights and chains. However, for commissioning purposes the only accurate way to check the calibration is to arrange for the contents of the belt to be weighed on a dormant machine.

The accuracy of a belt weigher depends not only upon the characteristics of the individual components of the weigher but also upon the belt weigher being correctly installed.

7.7 Density measurement

7.7.1 General

Many methods are available for the measurement of density. To produce accurate results it is essential that the most suitable design of instrument is selected for the application and correctly installed. When installing density measuring equipment:

a) with any of the sampling type of instruments, it is essential that the installation is arranged to provide a truly representative sample;

b) it is essential that the correct materials are used;

c) the instrument should be mounted in a position that is free from vibration.

The effect of temperature and pressure should be taken into account at the design stage, as temperature and pressure will affect the density of fluids. The effects are likely to be greatest near the critical point of the fluid, and are considerably more significant in the case of gases.

7.7.2 Weighing method

When installing a density meter:

a) the fluid sample should be clean enough to prevent blockages in the sample lines;

b) for liquid measurements, the instrument should be mounted in such a manner as to prevent gases entering the measuring vessel;

c) the mounting location should be free from vibration;

d) the sample lines should be connected in such a manner to allow free movement of the flexible couplings;

e) provision should be made, where appropriate, for the sample line, which takes the sample fluid away from the measuring vessel, to be piped back into the process or away to a suitable drain;

f) the instrument should be installed with a suitable means to ensure that the temperatures of the sample lines and the measuring vessel are maintained at the same temperature as the process. However, if the temperature of the process fluid deviates from that of the instrument sample fluid, then compensation should be made to the instrument output signal.

7.7.3 Buoyancy method

7.7.3.1 Principle

The density of a liquid can be measured by using a method that depends on the buoyancy of a float. In the buoyancy type of instrument the fluid to be measured flows up through a vessel containing a totally submerged buoyancy float tube. When the density of the fluid increases, there is a corresponding increase in the upwards thrust on the tube. By detecting the relative movement of the float, a direct indication of the liquid density is obtained.

7.7.3.2 Installation

When installing a buoyancy type instrument:

a) the fluid being measured should be free from solid particles and not prone to cause scaling;
b) the buoyancy vessel should be mounted in a vertical position;
c) the flow through the buoyancy vessel should be regulated to the correct value so that upward thrusts are generated by changes in density and not by changes in flow rate (especially important with high viscosity fluids);
d) the instrument should be free from vibration and mounted in a location that is not prone to vibration;
e) access should be provided to the buoyancy tube part of the instrument enabling regular checks to be made to ensure that there is no corrosion and no dirt deposits, etc., as their presence can seriously affect the accuracy of measurement.

7.7.4 Pressure differential methods

7.7.4.1 Principle

The density of a liquid can be obtained by measuring the pressure at the bottom of a fixed level of the liquid. In order to obtain an accurate measurement the liquid should not be subject to stratification (layering). The liquid in a vessel can be controlled at a constant level either automatically or by allowing it to overflow at a fixed point out of the vessel.

When the level of the liquid is held constant, any variations in the measured pressure at a fixed point in the liquid are due to variations in its density.

This differential pressure measurement can be carried out by any of the means described in **7.2** and **7.4**.

7.7.4.2 Installation

*NOTE For other installation recommendations, see **7.4**.*

When installing a differential pressure density measuring instrument, the head of liquid to be measured should be kept as large as possible in order to achieve accurate readings.

7.7.5 Nucleonic density measurement

7.7.5.1 Principle

This type of instrument depends for its operation on the relationship between the absorption of gamma radiation in a fluid and the density of the fluid.

A gamma radiation source is mounted on one side of the process vessel while the radiation detector is mounted on the opposite side. The amount of radiation received at the detector varies according to the density of the fluid.

7.7.5.2 Installation

*NOTE 1 Other installation recommendations are similar to those for level measurement using nucleonic techniques given in **7.4.8**.*

When installing a gamma radiation source and detector:

a) the safety recommendations applicable for the use of radioactive sources should be met (see Clause **4**);

   *NOTE 2 Attention is drawn to health regulations in respect of radioactive sources (see **4.16** and the commentary on **7.6.6**).*

b) access should be provided to enable regular inspections of the source to be made;

c) the source and detector should be installed in such a position on the process vessel that the fluid, whose density is to be measured, is always between the source and detector;

d) good mixing of the process fluid should be provided, particularly if the fluid to be measured has a tendency to settle in layers, e.g. caustic;

e) it is essential to check that the strength of the gamma source is correct for the particular application and that the commissioning stage adjustments are made to offset the absorption due to the density of the vessel wall material;

f) the source and detector should be aligned such that the path between them is uninterrupted by any moving parts, e.g. stirrers;

g) for liquid density measurements, the source and detector should be located in a position where gas entrainment in the liquid does not occur.

7.7.6 Ultrasonic method

7.7.6.1 Principle

The velocity of sound waves in a fluid varies according to the density of the fluid and this relationship can be used to determine the density of the fluid.

In a typical installation, an ultrasonic transmitter is mounted on one side of the process pipe or vessel and a detector of ultrasonic waves is mounted on the opposite side. The time interval between transmission and reception of the ultrasonic wave can be used as a measure of the density of the fluid.

7.7.6.2 Installation

When installing an ultrasonic density measuring instrument:

a) there should be optimum acoustic coupling between the transmitter/detector and the walls of the pipe or vessel;

b) the instrument should be mounted where there is good mixing of the process fluid;

c) the path of the acoustic waves should be arranged so as to avoid any distortions which might be caused by equipment inside the vessel such as stirrer shafts, submerged pumps and internal pipework;

d) the instrument should be mounted in a position on the vessel where the signal will not be distorted by gas entrainment in the liquid being measured.

7.7.7 Vibrating element (natural resonance) method

7.7.7.1 Principle

Vibrating element (natural resonance) instruments operate on the principle that if a fluid is contained by, or by part of, a body that is maintained in resonance at its natural frequency, then the frequency of resonance is dependent on the total mass of the system and so will change as the fluid density changes.

The vibrating element is normally in the form of a tube, cylinder or flat plate, and all forms may be used for both liquids and gases. The vibrating tube arrangement is mainly used for liquid density measurement since it provides a very clean flow path and is least affected by liquid viscosity. The vibrating cylinder is widely used for gas density measurement since it is able to achieve very high sensitivity whilst still being adequately rugged. The vibrating cylinder and flat plate forms are generally convenient for in-line (insertion) mounting. In general, these instruments are not sensitive to mounting position or normal plant vibration and they can achieve very high accuracy.

7.7.7.2 Installation of instruments for gases

When installing a vibration density meter for use on a gas, the following recommendations should be met.

a) The instrument should be installed in the gas pipeline in such a manner that the pressure and temperature of the gas in or around the sensing element is the same as that of the gas in the pipeline. If the bypass installation is used, the density meter body should be in close thermal contact with the pipeline. Care should be taken over the siting of any sample lines, isolation valves or filters to ensure that the pressure of the gas in the bypass density meter is the same as that in the gas pipeline. If the insertion instrument is used, it is expected that the temperature equilibrium will be ensured and the gas pressure will be within a fraction of a velocity head of the pipeline static pressure.

b) As these densitometers are highly susceptible to contamination, suitable filtering should be used, and care should be taken to prevent contamination during installation. In high accuracy metering installations, even fingerprints can be a source of error

c) The instruments will operate correctly only if the vibrating elements are kept dry. Hence the meter should be mounted in a situation where condensation will not occur. The instrument should preferably be kept dry during installation. In the vase of a bypass instrument, this should be installed only after all pipeline hydraulic testing and cleaning operations have been completed. An insertion meter should be installed only after all pipeline cleaning operations have been completed. If the meter is fitted for hydraulic testing, provision should be made to clean and dry the instrument after the test.

d) Special care should be taken with high pressure installations to ensure that the correct types of seals and fittings are used. The manufacturer's instructions should be carefully followed. Vortex shedding will occur around insertion meters. Care should be taken to ensure that the mounting arrangement will not allow mechanical resonance to occur at operating flow rates.

7.7.7.3 Installation of instruments for liquids

When installing a vibration density meter for liquid service, the following recommendations should be met.

a) The instrument should be mounted in a position where errors cannot be caused by gas entering or collecting in the measuring tube. On bypass density meters, a gas eliminator fitted before the density meter is expected to solve installation problems of this type. Insertion density meters should not be fitted immediately after pipe fittings, e.g. gate valves, where cavitation can occur, especially when being used on high-vapour pressure products.

b) The materials of construction of the instrument and associated fittings should be suitable for the fluid being measured.

c) When using bypass instruments, care should be taken to ensure that the temperature of the liquid in or around the sensing element is the same as that of the liquid in the process.

7.8 Multivariable transmitters/controllers

7.8.1 General

Modern instrumentation can combine multiple process variables within a single device, e.g. temperature and pressure. Further, the device can include computational power such that the process variables can be combined to generate a new variable, or to include compensation.

Multivariable devices can reduce the number of process penetrations, and their use should be considered during the design stage.

7.8.2 Installation design

Multivariable devices should be subject to the same considerations (e.g. safety, system integrity) as their single variable equivalents, taking due account of the manufacturer's specific instructions and plant safety requirements.

7.9 Quality measuring instruments

*COMMENTARY ON **7.9***
Quality measuring instruments measure chemical and physical properties of process fluids and substances, and are installed either directly in the process line, e.g. chemical probes for pH or thermal conductivity determination, or at a distance and connected by means of sampling systems, e.g. process analysers such as viscometers or chromatographs.

For expert advice and guidance it is recommended that a specialist is consulted.

*Density measurements are described in **7.7**.*

7.9.1 Chemical probes

7.9.1.1 General

There is a wide range of probes available for the measurement of a number of parameters. Installation details are described in the following subclauses for some of the more commonly used types.

Because of the nature of construction of the actual sensing elements, they are often fitted into an electrode holder which is mounted in a vessel bypass or process line.

The supplier normally specifies in detail all fitting requirements which, because of the delicate nature of the sensing elements, should be followed implicitly.

Clearance for fitting and removal of elements is vital and access for such should be checked.

Where the measuring system is fitted in a bypass, isolating valves and drain valves should be fitted to enable removal of the unit for cleaning and maintenance.

7.9.1.2 Electrolytic conductivity probes

NOTE Sensors without electrodes are manufactured in a variety of materials in order to withstand harsh environments such as highly corrosive chemical solutions and abrasive slurries. By virtue of their design and construction, maintenance is minimal.

Electrolytic conductivity is a measurement of the total ionic species in solution. In practice this can be related to the ionic strength, total dissolved solids or solution concentration. Measurement of conductivity can be seriously affected by variations in temperature, and temperature compensation should be considered during the design stage. Conductivity measuring cells are usually manufactured in four forms:

a) platinum, tantalum, PTFE and glass construction;

b) stainless steel construction;

c) carbon electrodes moulded in resin or plastics;

d) electrode-less sensors of various materials.

Platinum and glass electrodes are no longer commonly used. Their fragile construction makes reliable industrial application difficult and they also require regular re-platinization resulting in excessive down-time.

Stainless steel and moulded cells are of rugged construction and do not normally require frequent maintenance.

Conductivity cells are produced in a variety of mounting configurations suitable for use in virtually any type of plant fining.

Particular care should be taken when installing plastic bodied cells to ensure that thread sizes match and there is no confusion between, for example, BSP and NPT threads nor between taper and parallel thread fittings. Cells can be irreparably damaged through failure to check on thread details before installation.

During installation care should be taken to ensure that electrodes are free of any grease or dirt, as any such deposit will seriously affect the accuracy of the cell. The manufacturer's instructions for cleaning should be followed.

Signal cable installation should be in accordance with the manufacturer's requirements and Clause **15**.

7.9.1.3 pH probes

In its simplest form, pH measurement provides an indication of the acidity or alkalinity of the measured liquid.

pH measurement requires the use of both a measuring and a reference electrode. In most applications, temperature compensation is required and this should be accomplished by mounting a resistance element adjacent to the measuring electrodes.

Electrodes are usually designed for use in a dedicated housing or electrode holder. These units are supplied in a number of mounting configurations to suit particular applications, e.g. dip types for use in open tanks. pH probe systems should have arrangements to ensure that the probes are kept wetted at all times.

pH electrodes may be normally used without prior activation. For precise measurement, however, the electrodes should be soaked for 12 h in the specified buffer solution. After prolonged storage periods before installation, pH electrodes might require rejuvenating in accordance with the manufacturer's recommendations. Measuring and reference electrodes are normally supplied with some form of protection over their measuring surfaces; it is essential that this protection is removed before installation.

For calibration purposes the electrodes are immersed in two known buffer solutions whose value should encompass the required measuring range.

pH electrodes by nature of their construction are very high impedance devices (typically 10^{10} Ω) and as a consequence the transmitters, also having a high impedance, require great care when the interconnecting cables are prepared and fitted. Installation should be in accordance with the manufacturer's requirements and Clause **15**.

Where preamplifiers are employed they should be mounted as close to the electrode as is physically possible. This is to minimize the possibility of electrical pick-up or microphonically induced electrical noise, which is often encountered when long cables are used for the connection of sensitive high impedance devices.

Particular care should be taken to ensure that moisture cannot enter the cable system. Terminations and all plugs and sockets should be sealed to prevent any possible ingress of moisture.

Interconnecting cables are frequently prone to cause problems, hence the need for special care in their installation.

7.9.1.4 Reduction/oxidation (Redox) probes

The Redox potential is commonly used to determine the reduction or oxidation of an industrial waste during its treatment process by the measurement of the voltage produced. A solution that contains an excess of oxidizing agent has a positive potential, whilst one containing an excess of reducing agent has a negative potential.

The three most common measuring applications are:

a) destruction of cyanides;

b) treatment of chromates;

c) absorption of chlorine in sodium hydroxide.

The measurement of Redox potential requires the use of both a metal and a reference electrode mounted in systems similar to those used in pH measurement, and in general the same installation recommendations should be followed.

Depending on the application, silver, gold or platinum electrodes are used. Metal electrodes are generally supplied ready for use but might require degreasing prior to installation. Great care should be taken not to handle the metal billet or pin as this will lead to measuring inaccuracies.

After prolonged storage periods before installation, Redox electrodes can become oxidized and should be cleaned as recommended by the manufacturer.

7.9.1.5 Ion-selective probes

Ion-selective electrodes, for use with such chemicals as ammonia, fluorides, nitrates and chlorides, etc., are widely employed in industrial online analysis. They are normally installed in a dedicated ion-selective analyser and form part of that monitoring system.

The electrodes may take the form of glass, liquid membrane or solid state electrodes. In each case the probes should be assembled in accordance with the manufacturer's instructions.

Glass and solid state electrodes are normally supplied ready for fitting and require superficial checking only.

Liquid membrane electrodes are normally supplied in kit form for assembly on site. Great care should be taken in assembly to minimize the risk of premature failure.

7.9.1.6 Probes for measurement of oxygen in flue gas

Two methods of oxygen measurement are generally used:

a) utilizing the paramagnetic property of oxygen;

b) using a zirconia sensor to detect the movement of oxygen ions.

The sampling system for the paramagnetic analyser should be considered at the design stage, and the details supplied by the system designer and manufacturer should be followed. The position of the sample point is important. The gas sample is aspirated by steam, water or pump, and the aspiration system should be checked as soon as it is completed.

The zirconia probe is fitted into the process pipe or duct and, as position is important, all details should be settled at the design stage. The probe is part of a package and the detailed installation instructions should be obtained from the manufacturer. The following recommendations are of particular importance.

1) The probe is delicate and brittle, particularly when hot and therefore it is essential that it is not damaged.
2) All joints and sealing rings should be properly fitted.
3) The probe should be fitted in the correct position relative to gas flow, and the deflector should point upstream towards the flow.
4) The temperature control system for the probe should be checked but care should be taken to protect the analyser cell from any external voltages during such checks.
5) Where applicable, the cooling air supply should be clean and dry.

7.9.2 Process analysers

Process stream analysers and their sampling systems are generally complex and it is essential that they are properly applied and installed in order to ensure a high degree of accuracy with trouble free operation. There is a wide range of types and designs that cover numerous different applications in industry. This British Standard deals only with the features that are common to the various installations. The exact criteria for housing, supplies, services, sample conditioning, etc. applicable to each type of process analyser should be determined on a case-by-case basis.

To achieve reliable operation, it is essential that attention is given to the following:

a) protection against the environment;
b) accessibility for maintenance;
c) sampling systems;
d) distance of the analyser from the process line;
e) safety considerations.

Usually these will be taken into account at the design stage but they should also be borne in mind when installing the process stream analyser.

The installer might be required only to make the piping and electrical connections to a completely assembled and prefabricated analyser house. In other circumstances the installer might be required to install the analyser in a shelter and pipe up the sampling system. In either case it is essential to pay meticulous attention to details of the installation to insure that the performance of the analyser is not impaired.

7.9.3 Mountings and housings

Process analysers may be arranged centralized in groups, or installed in one of the various housings described in the list below, or individually mounted locally. There are a number of advantages in a centralized arrangement but in some circumstances, such as where it is essential to reduce sampling time delays, mounting them locally can have advantages. When mounted locally, the actual location in the plant where the process analyser is to be mounted should be determined at the design stage. Any brackets and supports that are used for mounting the analysers should be sturdy and suitably protected to prevent any deterioration if the site atmosphere is likely to cause harmful effects. When mounting process analysers that are sensitive to vibration, they should either be isolated from vibrations by suitable mountings or be located in areas where the level of the vibrations is unlikely to affect the analyser.

Housings for process analysers take a variety of forms depending on the degree of protection required:

a) *analyser case*: the enclosure forming part of the instrument;
b) *analyser cabinet*: a small simple housing in which analysers are installed singly or grouped together. Maintenance is carried out from outside the cabinet;
c) *analyser shelter*: a structure with one or more sides open and free from obstruction to the natural passage of air, in which one or more analysers and associated equipment are installed. The maintenance on the equipment is carried out from within the shelter;
d) *analyser house*: an enclosed building or space in which one or more analysers with associated piping, wiring and auxiliary equipment are installed. Either free or forced ventilation is used. The maintenance on the analyser equipment is carried out within the house.

Whichever type of housing is selected, it should be constructed of material that is resistant to fire and is impervious to any oils or chemicals that are likely to come in contact with it, both on the outside and on the inside. The housing should provide protection against wind, rain, frost and solar radiation.

Adequate illumination for maintenance is needed within the housing, so additional lighting should be provided where necessary. Additional heating should be provided when the ambient temperature is low and/or when the humidity conditions are likely to be high. When the ambient temperature is high or where there is a considerable release of heat from the equipment, it might be necessary to provide some form of cooling, e.g. from an air-conditioning system.

The analyser houses can be of substantial proportions, depending upon the numbers of analysers they contain, and the houses may be of brick construction, or prefabricated from sheet metal or glass reinforced plastics that have been treated with flame retardant additives. The house may form part of a package constructed and tested in a factory, the process analysers, sampling systems, heating, lighting, ventilation and safety devices being built into a transportable unit that is large enough to allow room for a person to walk in. Site installation of such a package then becomes a matter of placing the house in position and making the necessary connections to the site facilities and sample lines.

In the case where the building is constructed on site, the installation personnel should provide suitable supports on which to erect the analysers. Their tasks can also include the assembly of the sample conditioning systems, and installation of all the equipment such as junction boxes, wiring, lighting and electrical supplies. They should refer to the detailed design drawings and materials lists provided for site guidance as part of the installation documentation.

For safe operation, analyser housings should meet the requirements of BS EN 61285.

7.9.4 Sample conditioning systems

It is usually necessary to provide a sample conditioning system between the sample take-off point and the process analyser. Sample conditioning systems are designed to remove any undesirable solid or liquid contaminants in the sample and to adjust the temperature and pressure and the flow rate to the values suitable for the analyser. As far as possible the sample conditioning system should have no effect on the chemical or physical property being measured or alter the composition of the sample in any way that would influence the result of the final measurement by the process analyser.

Sample conditioning systems can be supplied complete with the analyser, or assembled in a site workshop or assembled at the location where the analyser is to be used. The components of an assembly can comprise pressure reducers, filters, variable-area flowmeters, coalescers, etc. mounted on a suitable framework. Stainless steel tubing and fittings are often used in the sample conditioning system. Other materials might also be suitable, but if in doubt expert advice should be sought. After assembly, the sample conditioning system should be pressure tested.

7.9.5 Sampling lines

Where the sensing device is installed directly in the pipeline, no sample loop is required. Where the sensing device is at a distance, sample lines should be used to transport the sample to the process analyser with the minimum of delay. If the distance is relatively short and a small amount of sample is required, only a single line from the sample to the process analyser might be necessary.

In many instances a fast circulating loop will be essential to reduce time lags or where it is unacceptable to vent or drain the sample. Plant pressure drops may be used to withdraw the sample from the process line and circulate it through the analyser. If the pressure drop is insufficient or is not reasonably constant, it might be necessary to provide sample pumps for the purpose.

When choosing material and fittings for the sample lines, it is essential that due account is taken of the material and piping classification of the process line or vessel from which the sample is drawn. Expert advice should be sought about the use of materials for special or corrosive service, e.g. flue gas, or where there is any possibility that the material of the sampling line could alter the composition of the sample. This is particularly important when the system is required to analyse traces of a chemical component or moisture.

Where plastics or other non-metallic sample lines are used, care should be taken to provide good supports so that there is no sagging. These sample lines should not be run in the vicinity of hot steam lines or where there is any risk that they will be affected by leaks from process lines, etc.

The layout of a sampling line should be arranged to avoid the formation of high points in liquid lines where gases and vapours could collect, or low points in gas lines where liquid could be trapped. Both will restrict the free flow of the sample. It might be necessary for sample lines to be heat traced by steam or electrical power, and thermally insulated to prevent changes in physical properties between the sample offtake and the analyser.

7.9.6 Sampling connections

A sampling connection, sensing device or sampling probe installed in a process line should not degrade the pressure rating of the line. Flanges or screwed connections should be of the same rating and material as the process pipework.

Isolation valves capable of tight shut-off should be installed between the sampling connection and the sampling line, and preferably should be full bore so as not to impose any restriction on the flow. The valve should have a means of indicating whether it is in the closed or open position.

Any sampling probe, or in-line sensing device, should be correctly positioned across the pipe diameter so that a fully representative sample can be taken.

7.9.7 Vent and effluent lines

Sample conditioning systems and process analysers might need to be connected to vent and effluent removal lines to remove any unwanted sample. Great care should exercised in locating the lines that carry the vent gas and effluent liquid so that they are discharged safely and do not cause a hazard to personnel and surrounding plant.

7.9.8 Manual sampling and calibration connections

A manual sample offtake for laboratory checks should be positioned so that the sample is representative of the liquid or gas entering the process analyser in such a way that the results of the laboratory measurement, and the analyser reading taken at the same time as the manual sample, can be compared without any error being introduced.

Calibration facilities to inject a known composition sample might also be required.

7.9.9 Storage and handling of equipment

As process analysers and their associated equipment are generally high cost instruments, it is essential to store them carefully and protect them from the weather when received from the suppliers and prior to installing them on site. Analysers should be carefully handled when being moved so as not to disturb or damage any delicate components which they might contain.

Any special precautions and instructions provided by the manufacturer should be strictly observed. Instruction manuals and any other documents that are attached to, or that accompany, the analyser should be handed over to the technical staff responsible for installation and maintenance.

7.9.10 Testing

It is most important that for testing and for the calibration procedures referred to in **7.9.11**, only instrument technicians who have the specialist expertise in process analysers should undertake this work. Where necessary, appropriate training should be provided.

The design specification should include a requirement for the process analyser to be tested at the manufacturer's works before delivery to site. Further testing will be necessary after it has been installed to check that the connections to associated equipment, such as recorders, programmers and computer input devices, are correct. Also, all mechanical equipment and connections should be thoroughly tested.

Service and sample connections to analyser houses should be tested in accordance with the general test procedures given in Clause **19**.

Special attention should be given to the analyser house interlock system (if fitted), particularly to the following items:

a) ventilation air flow sensing device;

b) any gas detectors that are installed in vent outlets;

c) the internal pressure device;

d) audible and visual alarms.

7.9.11 Calibration and commissioning

Inspection and testing should be so programmed that final calibration and commissioning can be completed just before start-up of the associated plant and thereby avoid a prolonged idle period.

7.9.12 Safety

When process analysers are used in connection with flammable and/or toxic materials, great care should be exercised to ensure that all aspects of safety have been properly dealt with. See Clause **4** for advice on personnel safety, and Clause **5** for recommendations concerning hazardous areas.

It is particularly important that any purging gas or ventilation air used as part of the electrical safety protective system is drawn from a safe source outside the hazardous area.

Special attention should be paid to the location, inspection, testing and commissioning of all process analysers that form part of a safety protective and monitoring system.

7.10 Fibre optic instrumentation

*COMMENTARY ON **7.10***
This subclause deals with instruments utilizing fibre optic sensing cables, which, in conjunction with signal processing, can provide one or a combination of parameters from a single device.

Fibre optic sensors may be single point or distributed, such that a single fibre can provide many measurements, effectively replacing multiple conventional sensors.

The measurable parameters detectable in a distributed system are temperature and strain, with ongoing developments to generate pressure sensing. Based on these three parameters, other parameters such as level and flow can be inferred.

Fibre sensors mounted in suitable sheathing can be applied to many applications such as:

- *monitoring refractory vessel skin temperature;*
- *suspended from ceilings for fire detection and environment temperature;*
- *power cable temperature monitoring;*
- *dam monitoring;*
- *pipeline leak detection.*

7.10.1 Principle of temperature measurement

Distributed temperature sensing (DTS) solutions utilize fibre optic technology to provide spatially distributed measurements over many thousands of individual points.

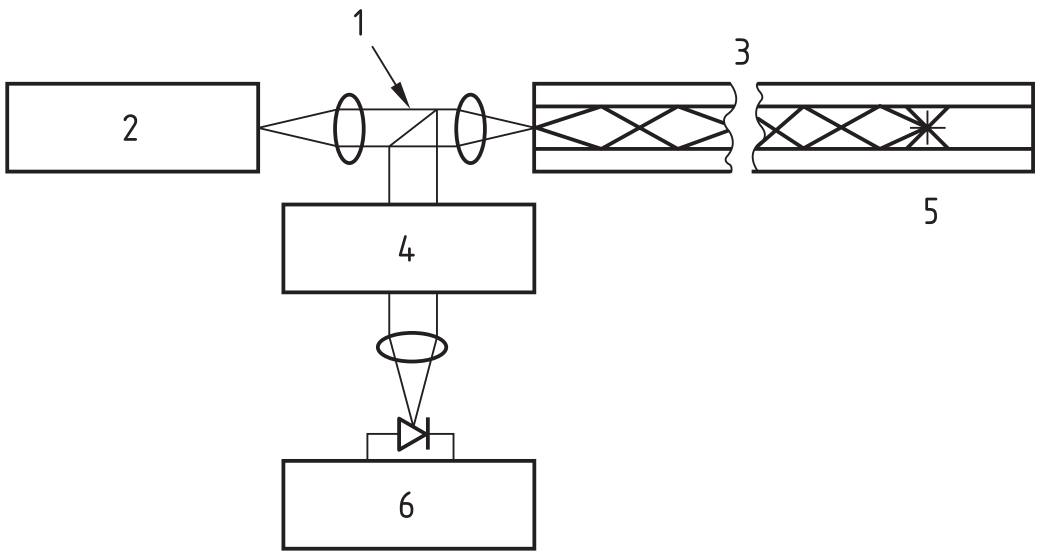
Based on analysis of Raman back-scatter signals in an optical fibre, DTS systems use a combination of variations in backscattered light intensity and reflectometry to create temperature against distance profiles.

The fibre acts as both sensing element and transmission medium. Many thousands of discrete measurement points can be achieved over distances of many kilometres using a single fibre.

In optical time domain reflectometry, it is the Rayleigh backscatter signature which is examined. The signal is unshifted from the launch wavelength. This signature gives information on loss, breaks and inhomogeneities along the length of the fibre.

A pulse of laser light is launched into the sensing fibre through a directional coupler (see Figure 26).

Figure 26 **Example of optical time domain reflectometry**



Key

1 Directional coupler
2 Laser source
3 Optical fibre sensor
4 Optical filtering
5 Raman scattering
6 Signal processing

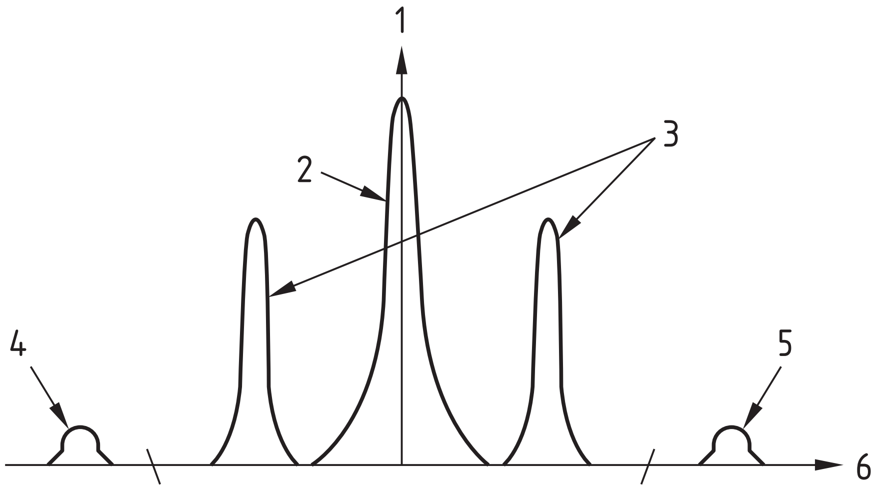
Light is scattered as the pulse passes down the fibre through several mechanisms including density and composition fluctuations (Rayleigh scattering) as well as Raman and Brillouin scattering due to molecular and bulk vibrations respectively (see Figure 27).

A proportion of this scattered light is retained within the fibre core and is guided back towards the source. The signal returned to the source is split off by the directional coupler to a receiver.

In a uniform fibre, the intensity of this returned light shows an exponential decay with time. Knowing the speed of light in fibre, it is possible to calculate the distance that the light has travelled down the fibre. Variations in composition, temperature, etc. along the length of the fibre show up as deviations from a "perfect" exponential decay profile of intensity with distance. Comparison of the measured profile with the reference reveals the distance along the fibre and magnitude of any temperature anomaly.

Raman signals comprise two elements – the Stokes and anti-Stokes lines – which are shifted in wave length from the Rayleigh signal and can therefore be filtered from the dominant constituent of the total backscattered light. The longer wavelength Stokes line is weakly temperature sensitive but the intensity of the backscattered light at the shorter anti-Stokes wavelength increases in proportion to the temperature rise and vice versa.

Figure 27 **Typical Raman and Brillouin bands**



Key

1 Incident light
2 Rayleigh band
3 Brillouin lines
4 Anti-Stokes Raman band
5 Stokes Raman band
6 Wavelength

By examining the information from the Raman signal and providing a data output, which graphically integrates this information, it is possible to monitor fibre optic cable to accurately and speedily notify the position and intensity of any temperature event along the fibre optic cable.

7.10.2 Principle of strain measurement

Brillouin scattering occurs when light in a fibre sensor interacts with density variations and changes its path. When the fibre is compressed, its index of refraction changes and the light's path necessarily bends.

The scattered light has a wavelength that is changed slightly by a variable quantity known as the Brillouin shift.

This phenomenon can be applied to the detection of movement in solid structures by bonding a fibre optic sensor to the structure. Lateral and torsional strain can be detected by suitable location and mounting of the fibre.

7.10.3 Fibre optic sensor installation

7.10.3.1 Fibre specifications

Optical fibres nominated or supplied by the system manufacturer should be used for guaranteed performance, however the actual fibre core used for this technology can be standard communications grade fibre.

Packaging of the fibre should be suitable for the environment in which it is to operate. A temperature sensor fibre should be suitable for the range of process temperatures likely to be encountered.

For direct fire detection, suitable sheathing, such as a sensor tube, should be used.

7.10.3.2 Installation

A fibre optic sensor has no electrical components. These fibres should be installed in the same way as fibre optic communication cables (see **15.6**), with due care being taken on bend radii, crushing and tensile load. However, unlike fibres for communications, fibre optic sensor cable might specifically require routing adjacent to or embedded in power cables for the purpose of monitoring strain and temperature.

Where a sensor tube is used, no additional fibre protection is required. Sensor tubes can allow easy replacement of fibres. A sensor tube can contain multiple fibres. Manufacturers' instructions for sensor tube installation, fibre replacement, sealing and maintenance should be followed.

The fibre or sensor tube should be bonded to the process sensing point as specified by the fibre supplier.

Hydrogen can cause darkening of optical fibres with continual exposure. Where hydrogen might be present, fibres should be suitably resistant or suitably protected. Where protection is not practicable, the fibre should be monitored and replaced before attenuation affects the required minimum performance.

7.10.3.3 Explosive atmospheres

The laser source should be located in an area consistent with the certification of the sensor control unit.

The laser power should be verified as suitable for connection to fibres terminating in or passing through hazardous areas, unless the cable and the terminating device are suitably certified.

8 Communication

8.1 SMART instrumentation

*COMMENTARY ON **8.1***
This subclause provides an overview of the technology of SMART instrumentation and presents an introduction to areas requiring attention in the installation and use of such technology.

SMART instrumentation is used in this British Standard to cover instruments which are equipped with additional digital processing facilities to provide extra functionality such as compensation, self-checking, diagnostics, and even to perform control functions within the device.

In general, SMART devices are used for analogue process variables, though in some cases analogue transmitters are replacing switches to improve reliability and diagnostics. Digital inputs are also supported by the use of multiplexers which can connect a number of switches to a single device which includes loop monitoring functions.

Typical communication standards for this type of device in the process industries are specified in BS EN 61158, the IEC 61784 series and IEC 61918.

General guidance on selection of fieldbuses is covered in BIP 0014.

Most SMART devices use digital communication for the transfer of information.

8.1.1 Analogue mode

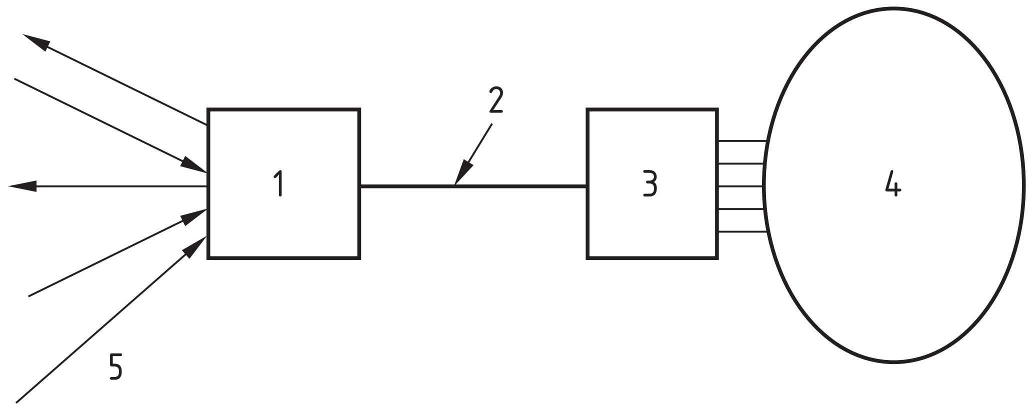
Some systems superimpose digital protocols over analogue signals.

Analogue instrumentation is generally cabled in a star configuration, i.e. each instrument is individually connected to a distribution point, such as a local junction box, and thence via multi-core cable to a central marshalling facility for connection to the control, monitoring or safety system (see Figure 28). Each instrument has its own dedicated set of cores, with the only commonality being any common earthing.

NOTE Depending on the design of the instrument, the internally measured PV may be digital or analogue. A digital internal PV will use a digital-to-analogue converter to produce the analogue output, in which case the digital value can be used to verify correct operation of the analogue processing. If the internal PV is analogue, then an analogue-to-digital converter is used to produce the digital PV. In this case the diagnostic value of the digital PV is reduced compared to the first case.

For analogue mode bus-based devices, the cabling should be installed in the same manner as for standard analogue instruments, and the process variable (PV) should be monitored in the same manner, e.g. 4 MA to 20 MA. However, superimposed on the analogue signal there will be encoded digital information, which can be retrieved via a purpose-designed interface to provide access to the additional diagnostics, which may include a digital value of the PV.

Figure 28 **Typical cabling topology for analogue instrumentation**



Key

1 Field junction box
2 Multicore
3 Marshalling
4 Control safety or monitoring system
5 Point to point for each device

8.1.2 Full digital mode

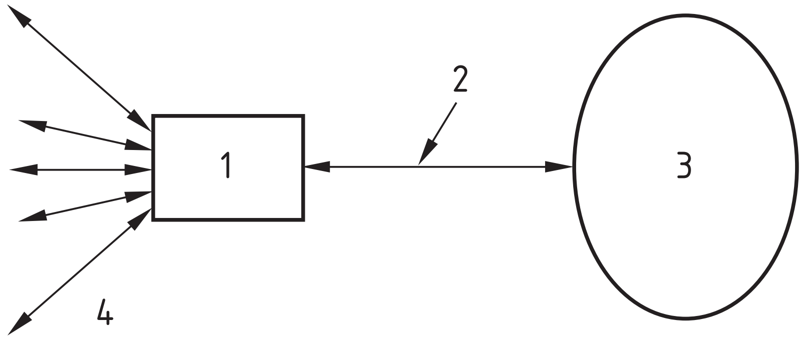
*COMMENTARY ON **8.1.2***
Fully digital networks generally follow two topologies, star or multi-drop (a ring topology is an enhancement of the multi-drop). In the fieldbus environment, other names are often used for these topologies such as "chicken foot" for a star configuration. The most common fully digital fieldbus configuration is the star (see Figure 29) due to the resilience.

IEC 62439 covers fieldbus configurations and profiles suitable for applications needing high resilience and redundancy in the communications.

Typically, multiple digital devices should be individually connected to a local hub or coupling device.

There will be a length of network cable (also called the trunk) connecting the hub to the host system. The trunk should be considered for redundancy and diverse routing for critical applications.

Figure 29 **Typical cabling topology for digital SMART instrumentation**



Key

1 Bus coupler

2 Trunk

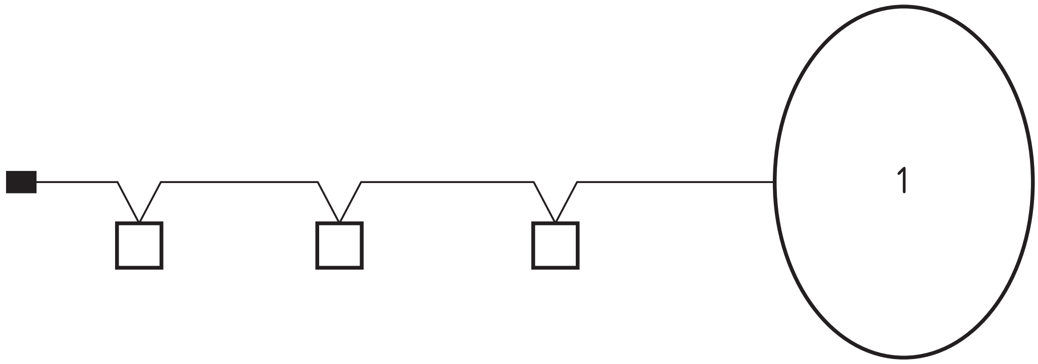
3 Control safety or monitoring system

4 Point to point

As an alternative to the star configuration, devices can be multi-dropped from a segment without a hub (see Figure 30). This allows a longer distance for distribution of devices but should be avoided due to the common mode failure of the segment, i.e. a single break can cause loss of multiple devices.

If this topology is required, the cable should be provided with additional protection against physical damage and/or redundancy. Suitable T-pieces might be required for this type of connection depending on the in-built facilities provided by the field devices, in which case the cabling topology design should take into account the location and accessibility of these components.

Figure 30 **Typical multi drop cabling topology for digital SMART instrumentation**



Key

1 Control safety or monitoring system

Fieldbus loops should include redundancy at the interface to the control system where available, but the segment cable and spurs are generally single. This is to limit the impact of failures as the interface at the control system may support multiple fieldbus segments. Devices are being developed which are expected to allow redundant segments and spurs to provide added resilience, in which case the cabling routes should be diverse.

NOTE Devices which use this type of cabling do not provide an analogue value, such that all information, including the PV, is digitally encoded. For this reason, this type of devices should not be used for high integrity safety applications due to the certification requirements. At the time of writing in 2008, appropriately certified digital devices were in development.

For critical control applications, the process dynamics should be at least twice as slow as the total digital processing time for the control system. In general, loop propagation times for bus-based devices are longer than for conventional devices.

8.1.3 Devices with function block support

Full digital mode devices can incorporate application programme (function block) support, such that functionality normally found in the process control system can be implemented between a selection of transmitters and actuators in a field environment. Consideration should be given to using this functional capability for applications where control autonomy in the field is beneficial to the overall process.

Function block support can also include additional diagnostic applications such as detection of impulse line blockage. If the process and installation area are likely to be prone to this problem, then devices with this feature should be specified.

8.1.4 Installation

SMART instrumentation should be installed in accordance with IEC 61918.

NOTE The instruments themselves require the same attention as standard instruments, but the added features of SMART instrumentation can provide more flexibility in the installation.

8.1.5 Quantities of devices

The design of a bus-based device network takes into account many factors which limit the number of devices on a particular segment. The type of fieldbus selected dictates a theoretical maximum, but bus-based systems need to balance a range of parameters to achieve the optimum performance (e.g. power loading, process time). The design of a segment should allow for later addition of devices without compromising the required performance.

A full review of the segment loading and performance requirements should be performed prior to adding additional devices to a pre-designed segment.

NOTE There are design tools available, usually from systems suppliers, to aid the design of segments to ensure that loading problems do not occur. Some buses require trading of device quantity, communication speed and total bus length; others have fixed speed and maximum length with restrictions on the number of devices dependent on power loading and process timing.

8.1.6 ATEX issues

NOTE There are limits as to how many bus-based devices can be installed in a hazardous area on a segment, and this limit can change depending on which standards are applied. Expert advice should be sought on this topic in accordance with the standards and guidelines applicable at the time of installation. For a given standard there is a limit to how much current can be supplied to the devices in the hazardous area. Refer to Fieldbus Intrinsically Safe Concept (FISCO) and Fieldbus Non-Incendive Concept (FNICO) (BS EN 60079-27).

A full ATEX compatibility analysis should be performed if one manufacturer's ATEX certified digital device is to be changed for an alternative equivalent device from a different manufacturer.

ATEX certified digital devices should be verified for which concepts they are approved and that they are suitable for the segment power conditioning applied.

8.1.7 Device compatibility

When designing a control system using bus-based smart devices, compatibility needs to be assured. Devices should be selected which have certification to validate their compatibility with the chosen standard, which in turn is expected to ensure compatibility with other devices certified to the same standard.

Rigorous techniques are applied by the certifying bodies for the fieldbuses, but incompatibilities can still occur. The version of the firmware in the device should be verified as being identical to that listed in the approved list of the certifying body. The certificate should also be verified for consistency with the actual device.

8.1.8 Device accessibility

Where possible, field instrumentation should be installed in easily accessible locations. However, there will be instances where this is impracticable. The enhanced diagnostics embedded in bus-based devices might allow routine maintenance from remote locations, conceivably from anywhere in the world, such that access is only required for physical repairs.

Devices that are used in analogue mode might require access to a local communications interface on the device, in which case this interface should be extended back to an accessible location. Some devices can provide a local wireless diagnostics facility.

NOTE Guidance on security measures is given in IEC/PAS 62443-3.

Where access from remote locations is possible (e.g. wireless fieldbuses, external web connections) then appropriate security measures should be implemented.

8.1.9 Cabling compliance

Bus-based device cabling should conform to given standards (see **15.7**). Once a standard is selected, the cabling for all devices on a segment should conform to that standard.

Cabling hubs can be provided with connectors which allow live disconnection without disrupting the bus operation even in a hazardous area, though the disconnected device will generate an alarm and might disrupt process operations.

8.1.10 Competency

NOTE A shortage of local skilled support can be offset by the advanced diagnostics and remote maintenance capability of the devices.

Bus-based devices are higher technology solutions than traditional systems, so the competency of the installation design, installation and maintenance personnel should be appropriate.

Competency should be relevant to the particular bus types in use.

Software problems may be resolved via remote access or even via the internet. However, if the system needs to be isolated from external access then personnel competent to use the system management tools should be available locally.

8.1.11 Management systems

*COMMENTARY ON **8.1.11***
Most control system suppliers capable of providing fieldbus solutions also provide management tools to aid their maintenance. These tools can be embedded in the control system or can be a higher level external database. Such tools provide a system database with an inventory of all devices connected to the control system. When a new device is added, it is automatically recognized by the control system and transferred to the management system database. All the necessary attributes of the device are automatically transferred to the database, and the device can be managed via this tool.

These databases can be linked to plant maintenance packages such that job cards can be generated automatically based on reported faults or predictive maintenance algorithms.

Management system databases can include analogue instrumentation, but the data for these devices is entered manually or imported from other databases.

The installation designer should review the plant requirements for management tools.

Safety certified devices used in analogue mode might require a management system for diagnostics monitoring in order to conform to their safety certification. When selecting devices for safety applications, verification should be made of any dependence on the digital diagnostics and associated management systems.

8.1.12 Instrument data sheets

Where manual records are being maintained for instrumentation, additional information should be recorded for bus-based devices. As a minimum the following additional data should be recorded:

- bus type;
- firmware version;
- software version;
- test tools applicable;
- test procedures applicable.

8.1.13 Safety-related devices

*COMMENTARY ON **8.1.13***
SMART devices installed in safety loops generally operate in analogue mode for the process variable or actuation, with the digital functions providing additional diagnostics. The range of parameters accessible via the digital interface may be limited or a full set may be made available.

NOTE Fully digital safety certified devices may be selectable for normal use and safe use. The safe use setting may activate additional diagnostics and firewalls in the device communications (referred to as Black Channel). Devices may only be allowed to communicate with each other if the safety settings are consistent, thereby allowing safe devices to share the same bus as normal devices.

Remote re-ranging of a transmitter on a safety loop should be disabled as the consequences could lead to inhibiting of a trip function at the designed value.

Adjustment access should be locked out and controlled unless there is justifiable cause to defend this operating regime.

This raises a new layer of device management and installation issues to ensure that during the lifetime of a plant, the integrity of the safety loops is maintained. Before instigating such systems, expert advice should be sought.

8.1.14 Safety-related fieldbuses

*COMMENTARY ON **8.1.14***
Safety-related digital communications use the classifications White Channel and Black Channel. White Channel communications inherently provide a sufficient degree of integrity for secure applications. All normal fieldbus communications are Black Channel. A number of fieldbus profiles for safety-related applications are identified in IEC 61784-3. These achieve White Channel performance by adding additional design features and protocol checks to the basic fieldbus.

Black Channel communications are common as the integrity is not affected by communication devices in the network, therefore standard communications equipment can be used subject to performance limitations being addressed.

Fieldbuses certified for safety are available. Such buses are generally applied to communications between safety controllers or to remote IO systems, however they may be used to connect to individual devices.

Digital mode devices selected for safety applications should be verified for compliance with interoperability to the relevant bus standard, in addition to safety compliance with BS EN 61508 (interoperability is verified by confirming that the device and version are appropriately listed on the website of the relevant bus foundation).

Specialist advice should be sought when designing safety loops with full digital mode technology.

8.2 Security of communications

*COMMENTARY ON **8.2***
SMART instrumentation supports remote maintenance by means of digital communications. A key benefit of this technology is the reduction in the need to physically access the instrumentation except for mechanical or electrical faults.

Remote instrumentation may be connected by cable and/or via wireless links, with the same security issues applying in each case, but wireless systems need to take greater cogniscence of interference. See IEC/PAS 62443-3.

8.2.1 Internal connection security

*COMMENTARY ON **8.2.1***
Remote access might be required by multiple parties. The plant operator might require remote access for routine maintenance and diagnostics, whereas a device supplier might require remote access for more invasive diagnostics, repair and even software upgrades.

Remote access to smart instrumentation may be provided by two primary routes:

- *via the plant control/safety system;*
- *via direct access to the device or its local controller.*

There are key differences to the manner in which security is applied to these two cases. See IEC/PAS 62443-3.

The following recommendations should be met to maintain the security of internal connections.

a) Remote access should be strictly restricted to authorized persons and activities.

b) Access via the plant control/safety system should be made secure by the use of firewalls between the system network and open networks.

c) Access from within the system network should be restricted by software passwords and/or by hard key switches (the latter should be considered for safety systems) at the operator interface.

d) Access to all operator and maintenance interfaces should be controlled by physical security to the rooms and site.

e) Access via the device itself or a local controller should be made secure by software access control within the device or its local controller. This should be supplemented by remote access restrictions if practicable.

f) Plant operator access security should be an embedded part of the control or safety system.

g) Device supplier access should be an embedded part of the system under the jurisdiction of the plant operator.

8.2.2 External connection security

The following recommendations should be met to maintain the security of external connections.

a) Remote support access should provide at least the same level of system security as the internal connection system. The external connection should be the total responsibility of the system owner.

b) Physical security should be provided for remote connections. This should involve the communications link only being physically made at a known and controlled time by the system owner. For example, a modem should not be connected to the telephone network in normal conditions.

c) Dial back facilities should be used, whereby external connection is made by the system responding only to known network addresses or telephone numbers.

d) Where connection is via a virtual private network (VPN), due care should be taken to logically control access to the system.

e) Rigorous port filtering should be configured to reduce the potential for stealth access. System suppliers may reserve a port open for remote support. It should be verified if this is the case and such access should be restricted to a user-controlled port.

f) Computer operating systems provide the means to add encryption to external communication links. This encryption can be applied to the link itself and/or to the data to be transmitted. Some form of encryption should be implemented as appropriate to the data relevance and system capability.

g) Secure network switches configured to recognize authenticated network devices and protocols, filtering out alien activity, should be used wherever practicable.

h) Security and interoperability should be taken into account when designing external connections. Whichever means of security is applied, it should only allow access from authenticated devices and/or users.

i) All remote access for the purposes of software modifications should be via controlled interfaces with the applicable security measures enforced.

8.2.3 Wireless security

*NOTE Recommendations for the selection, topology and use of wireless systems are given in **8.3**.*

The following recommendations should be met to maintain the security of wireless connections.

a) Wireless instrument networks should be provided with embedded security to protect against unauthorized manipulation of process values and actuator actions. There are a number of encryption methods available with varying levels of protection. The chosen level should be consistent with the assigned process importance and risk.

b) Encryption technology is constantly changing to meet growing usage of wireless facilities. Security and interoperability should be taken into account when designing wireless systems. Whichever means of security is applied, it should only allow access from authenticated devices and/or users.

c) Wireless networks can be disrupted by the generation of suitable interference. This can disrupt operation of the process as opposed to forcing it to a specific state. Suitable investigation should be performed to reduce the possibility of interference sources consistent with the assigned plant/process importance and risk.

8.3 Wireless instruments

*COMMENTARY ON **8.3***
At the time of publication of this British Standard, there are no national or international standards for the design, installation, testing and maintenance of wireless instrumentation systems. This subclause gives guidance on the selection, topology and use of such systems.

Field transmitters and actuators are available which do not require the physical infrastructure of cabled devices. This makes many installation design issues easier, but there are new considerations to be taken into account.

The definition of a "wireless device" can vary widely. A truly wireless device will not have any physical connection to power or communications *infrastructure, relying on local battery power for its energy source. However, some devices have a wired power supply and wireless communications.*

A wireless instrument network can be one or several topologies: star, cluster, tree or mesh (see Figure 31 for a diagrammatic representation of the different topologies available).

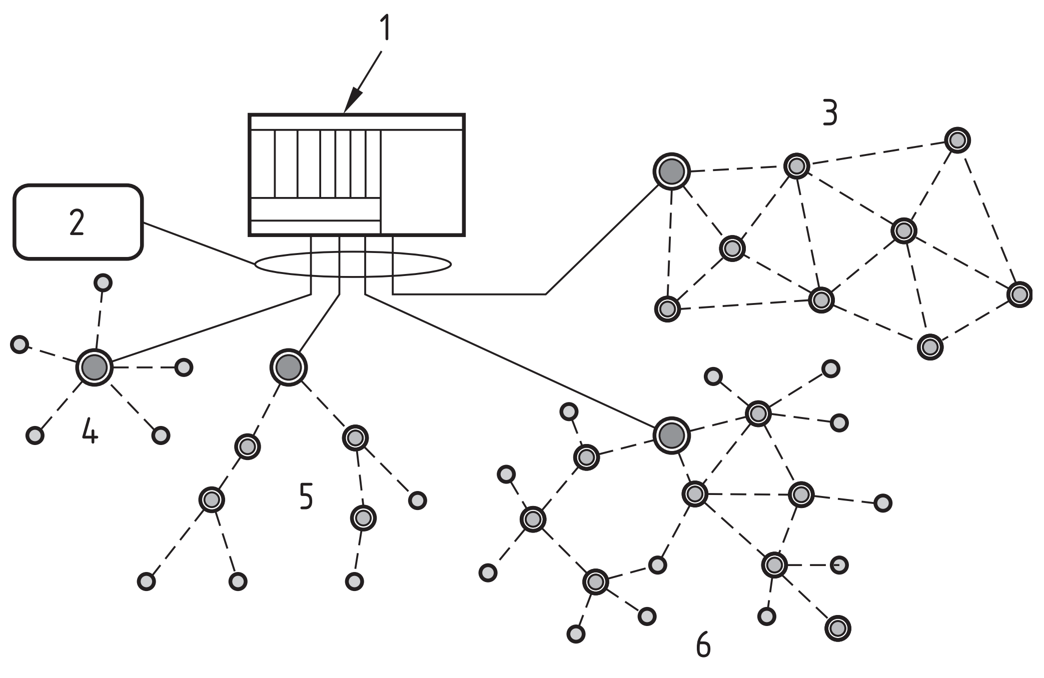
The use of wireless devices is heavily regulated throughout the world, with each country having a government department responsible for deciding where and how wireless devices can be used, and in what parts of the radio spectrum. Most countries (but not all) have allocated parts of the spectrum for open use, or "license-free" use. Other parts of the spectrum can only be used with permission or "license" for each individual application.

Most wireless devices for short-range industrial and commercial applications use the license-free areas of the spectrum. The license-free bands are also knows as industrial, scientific and medical (ISM) bands. In many countries there are several ISM bands available, in different parts of the spectrum.

For information on all bands assigned in the UK, refer to the United Kingdom frequency allocation table [57], available from the Department of Trade and Industry.

For specific restrictions relating to UK ISM bands, refer to the OFCOM UK interface requirement 2005 [58].

Figure 31 **Typical topologies for wireless instruments**



Key

1 Controller
2 Transport to topology
3 Mesh
4 Star
5 Tree
6 Cluster

8.3.1 Selection of wireless instrumentation

The following issues should be taken into account when selecting wireless instrumentation.

a) Prior to any design commencing on a wireless instrument network, the regulatory requirements for the specific installation location should be ascertained.

b) Prior to commencing the network design, a radio survey should be performed at the intended location. This survey should include the identification of external sources of interference, external systems which could suffer from interference, and local site topology issues which could influence intra network communications. Radiological surveys should not be snapshots; they should identify changing conditions and known future developments.

c) The choice of radio network topology should be based on the results of the radio survey combined with the required security, purpose and performance of the network. The full performance characteristics should be defined for all operating conditions prior to the network topology being selected.

d) The selection of the appropriate wireless technology is an important consideration since there are many types of wireless protocols with many trade-offs in capability and suitability for various applications. It is recommended that specialist advice be sought when considering the optimal type of wireless solution for a particular requirement.

NOTE Instrument networks providing process control often have higher demands on network speed, security and availability than those providing only monitoring.

8.3.2 Power management

8.3.2.1 Battery-powered devices

Wireless devices relying solely on battery power should be subjected to a controlled regime of battery management.

Battery life is influenced by many factors including storage prior to use, operational environment and powered device settings. Some devices provide indication of the battery condition as part of the device diagnostics. Devices with this feature should be selected where practicable.

Large wireless installations can require a high overhead for battery management. Suitable tools and procedures should be implemented to manage the replacement of batteries predictively.

Wireless devices can be installed in difficult and not easily accessible locations. Access to such devices should be taken into account as part of battery management.

Battery replacement activities should take due cogniscence of any ATEX certification of the device.

8.3.2.2 Alternative powered devices

For devices that have a wired power supply, the recommendations for earthing (see Clause **16**) should be followed.

8.4 Fibre optic device communication

*COMMENTARY ON **8.4***
Developments in fibre optic technology are resulting in devices using direct fibre connections for their signal interface. There are a number of advantages to this technology as the data connection is fully isolated from the power infrastructure with reduced earthing restrictions.

Fibre optic switches with no moving parts, and use of Fibre Bragg Gratings, allow many devices to share one fibre with high bandwidth for diagnostics data per device. Interference from other electrical equipment is easier to manage.

Termination of fibre optic cables to devices should follow the device manufacturer's instructions.

8.5 Modems

Modems should be connected to the data transmission line and the data source in accordance with the manufacturer's recommendations for the particular application.

If a modem is connected to the public telephone network, it should be approved for use with the appropriate network provider.

9 Pollution prevention and control

*COMMENTARY ON CLAUSE **9***
There is a legal requirement for operators of certain industrial processes to have a permit for emissions to air, water (including sewers) and land, and other environmental affects including energy efficiency, waste reduction, raw materials consumption, noise, vibration and heat, accident prevention and site conditions. The installation operator is also required to have in place a quality management system covering environmental requirements. There are general requirements and specific requirements for some processes that require the operator to implement a site protection and monitoring programme. They might require specific monitoring methods, or there might be European or UK guidance. Before environmental monitoring instruments or systems, which can also be a part of the process instrumentation, are installed, it is necessary to confirm that they will meet the requirements of the installation operator's permit in accordance with their environmental quality system, and that they are fit-for-purpose.

*NOTE 1 See Clause **4** for environmental issues that can affect health and safety at work.*

NOTE 2 Attention is drawn to Defra's guide on integrated pollution prevention and control [59], available at www.defra.gov.uk.

NOTE 3 European guidance documents for particular processes are in the form of BREFs, which are available at http://eippcb.jrc.es/pages/FAcitivities.htm.

NOTE 4 UK guidance documents for local authority regulated processes are available at http://defra.gov.uk/environment/ppc/localauth/pubs/guidance/notes/index.htm. They are in the form of Process Guidance notes (PG notes), Sector Guidance notes (IPPC SG notes), and Air Quality notes (AQ notes).

*The regulations concerned with pollution prevention and control are the Pollution Prevention and Control (England and Wales) Regulations 2000 [60] and related legislation (see Table A.1). Subsequently, the Environmental Permitting (England and Wales) Regulations 2007 [61] amended the pollution prevention and control legislation by replacing "PPC permit" with "environmental permit", which embraces all environmental legislation that might be applicable to an installation, such as that on emissions of solvents and titanium dioxide, and emissions from incinerators and major power plant. Existing PPC permits automatically became environmental permits on 6 April 2008; outstanding applications for PPC permits will automatically be issued as environmental permits if approved and all new applications now have to be for environmental permits. Any reference to a permit in **9.1** to **9.4** should be construed as an environmental permit.*

NOTE 5 Attention is drawn to the following Defra guides:

- *Environmental permitting – List of guidance and glossary [62];*
- *Environmental permitting – Environmental permitting core guidance for the Environmental Permitting (England and Wales) Regulations 2007 [63];*
- *Environmental permitting – Environmental permitting guidance – The IPPC Directive Part A(1) Installations and Part A(1) Mobile Plant – For the Environmental Permitting (England and Wales) Regulations 2007 [64].*

NOTE 6 Users of this British Standard are advised to consider the desirability of using instruments that have been certified to the Environment Agency's MCERTS scheme. The MCERTS scheme formally covers England and Wales, but the Scottish Environmental Protection Agency and the Department of Environment Northern Ireland are supportive of it.

9.1 General

It should be confirmed that the monitoring technique, method and instrumentation are appropriate to the process being monitored and, where needed, sample locations and their numbers are adequate to ensure representative sampling of the discharge being monitored.

NOTE PEMs use a computer model with predictions based on process data or generic emission information where emissions are relatively consistent, such as gas turbine installations.

Data acquisition systems should be computer-based (computer, DCS, PLC, discrete hardware, data loggers etc.) and should be confirmed to be in accordance with the conditions of the environmental permit. They should provide automatic calibration, diagnostics, data analysis facilities, with trending, alarms, etc. and software should be password protected, as should predictive emission monitoring systems (PEMs).

9.2 Stack emissions to air

9.2.1 General

WARNING. Working at height on stacks when installing, maintaining or calibrating permanent sampling equipment is particularly hazardous. In addition to the physical risks of working at height, there are risks from the weather, exposure to flue gases and exposure to substances used in monitoring tests and analysis and cleaning. Before commencing work it should be ensured that the site risk assessment has been adequately performed and appropriate controls are in place. All personnel should comply with the safety recommendations in Clause **4** and work platforms should conform to the requirements in BS EN 13284-1 and BS EN 15259.

NOTE 1 Further information on stack emission monitoring is available from Environment Agency Technical Guidance Note M1 [65], and from Risk assessment guide: Industrial-emission monitoring, published by the Source Testing Association [66].

Information should be made available from the site survey identifying the nature of the process before sampling of the stack gas for the first time; for example, whether it is a steady state or cyclic process, and what the feedstocks and material balances are.

Before installing permanent instruments and systems for regulatory purposes, it should be confirmed that the stack gas has been assessed in accordance with BS ISO 10396, BS ISO 9096 and BS EN 15259. Suitably qualified personnel should have assessed the stack gas.

NOTE 2 Personnel certified to the Environment Agency's MCERTS are deemed to be suitably qualified to assess the physical and chemical characteristics of stack gases.

The choice of periodic manual, periodic instrumented or continuous emissions monitoring (CEMs) should take into account the process, nature of emissions and the requirements in the installation operator's environmental permit. Periodic monitoring is normally acceptable when sampling a batch process, and whether this should be manual or automatic depends on the variability of the emissions, which dictates the frequency of monitoring as well as the suitability of the specific method employed. Where emissions vary frequently, such that periodic measurement would not be representative, automated CEMs should be used.

NOTE 3 Guidance on selection of methods for regulatory monitoring is given in Environment Agency Technical Guidance Note M2 [67]. It provides information on each type of monitoring, the techniques and principles employed, relevant standards, including British Standards, and the application, strengths and limitations of each method for each determinand.

Monitoring should be carried out in accordance with BS EN 15259, which applies to periodic measurements using standard reference methods, automated measuring systems or CEMs. This standard specifies generic principles and gives minimum requirements for the measurement planning, measurement strategy and reporting of emission measurements of air pollutants, and reference quantities to be carried out in exhaust ducts at plants, It also gives minimum requirements for the design and construction of a plant with performing emission measurements to air. Periodic monitoring should be carried out in accordance with DD CEN/TS 15675.

NOTE 4 Guidance on the measurement and monitoring of volatile organic compounds to air from industrial installations is given in Environment Agency Technical Guidance Note M16 [68].

NOTE 5 The Environment Agency, where necessary, produces Method Implementation Documents (MID) to support standard methods. MIDs have been published for BS EN 13284-1 [69], BS EN 14385 [70] and BS EN 1948 [71].

NOTE 6 Stack emission measurements require defined and stable flow conditions at the sample location. This allows the velocity and concentration of the measured component in the stack emission to be determined. If suitable sampling facilities are not available it will mean that sampling of pollutants cannot be carried out in compliance with the required sampling methods. This means the uncertainty associated with the results is greatly increased. In these circumstances, meaningful results from stack emissions monitoring cannot be achieved.

9.2.2 Periodic sampling

NOTE 1 Attention is drawn to Environment Agency MCERTS Method Implementation Document MID 1 [69], relating to BS EN 13284-1.

NOTE 2 Guidance for positional requirements for periodic sampling is given in Environment Agency Technical Guidance Note M1 [65].

The position and number of sampling facilities for particulate measurements should be in accordance with BS EN 13284-1, BS ISO 9096 or BS EN 15259 as appropriate. Before installing equipment, it should be confirmed that the gas flow-stability criteria (velocity and direction) at the sampling points are correct, and the sampling points have been agreed with the equipment manufacturer and installation operator. These standards give recommended sampling locations. However, if the flow-stability requirements are not achievable then alternative locations should be identified.

Location requirements for measuring gas concentrations are less exacting than those for monitoring particulates, and depend on the homogeneity of the gases and a positive gas flow. The position and number of sampling facilities for gas concentration measurements in homogenous gas flow should be in accordance with BS ISO 9096, BS ISO 10396 or BS EN 15259 as appropriate. Before installation of equipment, the homogeneity of the gas flow should be determined at sampling locations specified in these standards. If the gas is homogenous then only one sample point is needed. If the gas is inhomogeneous a different sample location should be identified or a grid measurement approach used. Where mass emission rates and gas concentrations are required to be monitored, the sampling locations should be the same as for particulates. The sampling locations should be agreed with the equipment manufacturer and installation operator.

9.2.3 Continuous emission monitors (CEMs)

A CEM system is not only the analyser, but also includes:

- facilities for taking samples (e.g. probe, sample gas lines, flowmeters and regulator, delivery pump);
- facilities for sample conditioning (e.g. dust filter, pre-separator for disturbing components, cooler, converter);
- facilities for recording;
- any necessary testing and adjusting devices for commissioning and functional checks.

It should be confirmed that the analyser manufacturer has supplied all the necessary components or identified suitable components and their manufacturers.

NOTE 1 The requirements of BS EN 15267-3 are applied in the UK through the Environment Agency's MCERTS scheme.

NOTE 2 Attention is drawn to Environment Agency performance standards for gaseous emissions, particulates, temperature, pressure and flow rate [72].

CEMs for monitoring both gases and particulates should meet the requirements specified in BS ISO 10155; BS EN 13284-2:2004, QAL1; BS EN 14181 or BS EN 15267-3 as appropriate. CEMs should be assessed for suitability for the determinands to be measured, range for the process where it is being applied, integrity of monitoring data in the specific stack conditions, operating temperature range and documentation to ensure continuing functionality.

NOTE 3 Attention is drawn to the Environment Agency Method Implementation Document MID 13284-2 [73].

NOTE 4 Guidance for positional requirements for continuous emission monitoring is given in Environment Agency Technical Guidance Note M1 [65].

Positional requirements for sampling particulates and the minimum number of sampling points are given in BS EN 13284-2.

Sampling positions for CEMs that measure gases should be in accordance with BS ISO 10396 or BS EN 15259, and positions for CEMs that measure gas volumetric flow rate should be in accordance with BS ISO 14164.

The location of a non-intrusive CEM should be within one duct diameter or 1 m, whichever is smaller, upstream of the sample ports for manual sampling and generally vertically in line with one of them. For intrusive CEM the location should be two duct diameters or 2 m, whichever is smaller, upstream of the manual sampling ports and generally at 45° to one of them.

CEMs should be installed in accordance with the manufacturer's instructions wherever possible, but where this cannot be done because of sampling point problems, e.g. in old stacks, installation should only take place following consultation with the manufacturer and site operator.

After installation, CEMs systems should be checked for alignment, cleanliness, sampling system integrity, leaks, manual zero and span, linearity, interferences and response time.

NOTE 5 It is a requirement of BS EN 14181 that QAL2 validation and calibration is carried out using standard reference methods and suitably qualified personnel meeting a level of competence specified by the competent authority. BS EN 13284-2 elaborates on the requirements of BS EN 14181 for particulate-monitoring CEMs. For installations where BS EN 14181 does not apply, the principles of this standard can still be applied for the quality assurance of CEMs. BS ISO 10155 describes the performance and calibration requirements for particulate-monitoring CEMs, and is useful for installations where BS EN 13284-2 does not apply.

NOTE 6 Guidance on the quality assurance of CEMs to BS EN 13284-2 and BS EN 14181 is given in Environment Agency Technical Guidance Note M20 [76].

NOTE 7 Personnel certified to the Environment Agency's MCERTS are deemed to be suitably qualified to carry out validation and calibration of CEMs.

Calibration of CEMs systems fitted on installations falling under the Large Combustion Plants (England and Wales) Regulations 2002 [74] or the Waste Incineration (England and Wales) Regulations 2002 [75] and related legislation (see Table A.1) should be carried out in accordance with BS EN 14181.

9.3 Monitoring discharges to water and sewer

NOTE Attention is drawn to the Environment Agency Technical Guidance Note M18 [77] and to the MCERTS performance standards for continuous water monitoring systems [78, 79, 80].

9.3.1 Monitoring discharges to water and sewer

NOTE The Environment Agency has set limits for analytical uncertainty. Analytical instruments certified to MCERTS are expected to meet the requirements if correctly installed and used as intended. Guidance on sampling and off-line analysis is given in Technical Guidance Note MI8 [77], which also lists the relevant British Standard/Environment Agency SCA Blue Book for the measurement of each determinand that has to be monitored.

Monitoring discharges to water and sewer may be periodic, through sampling for laboratory analysis or use of portable instruments, or continuous, using automated water-sampling or monitoring systems (CWMs). The type of monitoring required is specified in the environmental permit for some specific processes in order to meet regulatory requirements. Before installation it should be confirmed that the monitoring equipment and its measurement uncertainty is suitable for the installation operator to comply with the environment permit, and that the sample positions in pipes and channels are sufficiently downstream of the last inflow for mixing to be complete. The sampling points should preferably be in regions of high turbulence and good mixing, usually at the centre of the discharge.

9.3.2 Automatic wastewater samplers

NOTE For performance requirements, attention is drawn to Environment Agency MCERTS performance standards and test procedures for automatic wastewater sampling equipment [78]. MCERTS certified equipment has been third-party tested and approved in accordance with these procedures.

Before installing automatic wastewater samplers, it should be confirmed that the following information has been supplied by the manufacturer:

- the maximum volume of a discrete sample that can be set;
- the total storage capacity, by both number(s) and volume(s) of individual bottles and in a composite container;
- the maximum sampling head;
- any specific installation requirements.

9.3.3 Online analysers

NOTE For performance requirements, attention is drawn to Environment Agency performance standards and test procedures for online analysers [79]. MCERTS certified equipment has been third-party tested and approved in accordance with these procedures.

Before installing online analysers, it should be confirmed that the manufacturer has supplied the following information:

- the storage life and requirements for spares and reagents;
- any special equipment required for the storage of spares and reagents;
- the reference values and rated operating conditions for sample flow rate, temperature and pressure as appropriate;
- any specific installation requirements.

9.3.4 Flowmeters

NOTE For performance requirements for flowmetering systems, attention is drawn to the Environment Agency's MCERTS performance standards and test procedures for water flowmeters [80]. MCERTS certified equipment has been third-party tested and approved in accordance with these procedures.

When assessing the suitability of the selected measurement method, the uncertainty requirements should take into account all components of the flow measurement system and the nature and flow rate of the application.

Before installing a flow measurement system, it should be confirmed that the manufacturer has supplied an upstream strainer or filter if one is needed to protect the flowmeter, together with the following information:

- the minimum upstream and downstream straight lengths of conduit or channel adjacent to the sensor;

- any limitation on the material, dimensions, shape or wall thickness into or onto which the flowmeter sensor can be installed;
- the nature and quantity of particulate or other material that the meter can or needs to pass to maintain performance;
- requirements for location and protection of components;
- rated operating conditions for fluid pressure, if appropriate;
- the minimum separation distance from the sensor face to the fluid surface for non-contact level sensors;
- the maximum and minimum separation distances from the sensor face to the fluid surface for non-contact velocity meters;
- the minimum measurable fluid depth under free surface conditions for flowmeters for use in partially filled pipes.

9.4 Energy efficiency

*COMMENTARY ON **9.4***
Under the Pollution Prevention and Control (England and Wales) Regulations 2000 [60], there is a specific requirement for installations to be operated in such a way that energy is used efficiently. When applying for a permit, the site operator has to provide a description of all energy used in, or generated by, the installation. Energy efficiency has to be taken into account when determining best available techniques for the prevention and minimisation of pollution from the installation. All installations falling under IPPC have to meet a set of defined basic energy requirements for energy efficiency. These are based on the implementation of generic, low-cost methods designed to address gross inefficiencies only. Additional requirements have to be met, either through participation in a Climate Change Agreement or Emissions Trading Scheme Direct Participation Agreement with the Government, or through compliance with further permit-specific requirements as determined by the Regulator.

*NOTE 1 See also **10.10** on variable speed drives.*

NOTE 2 Attention is drawn to Horizontal Guidance Note IPPC H2 [81].

It is a legal requirement that equipment or procedures are in place for the continuous measurement and assessment of energy use (in MWh) within the installation, including all energy imported directly form external sources (heat, power and energy from renewable sources) and fuels converted to energy within the installation. The installation design should include monitoring and recording instruments for all sources and forms of internal and external power.

9.5 Electromagnetic compatibility (EMC)

*COMMENTARY ON **9.5***
It is a legal requirement that equipment (apparatus and fixed installations) that contains electrical and/or electronic components and is not inherently benign (not liable to cause electromagnetic disturbances and not affected by such disturbances during normal operation) conforms to relevant regulations for protection of the electromagnetic environment. There has to be a person or persons responsible for establishment of compliance of a fixed installation. Electrical/electronic apparatus that is commercially available has to have the CE marking if it is subject to the EMC Regulations [21], i.e. it is not inherently benign. Apparatus that is not commercially available and is only intended for a particular installation does not have to have the CE marking for EMC Regulations, but it does have to meet the protection requirements. Manufacturers of electrical/electronic apparatus are required to supply instructions for installation and use so that compliance with regulations can be maintained. These instructions are required to contain any restrictions on use in installations in or adjacent to residential (domestic) areas. The person responsible for the installation is required to keep documentation sufficient to demonstrate that good engineering practices have been followed in the installation.

Attention is drawn to the need to confirm before installation that all apparatus conforms to EMC Regulations [21]. It is advisable not to rely on CE marking alone for establishing conformity to the Regulations.

The Regulations only apply to the protection of the electromagnetic environment. They do not apply to the interoperability of equipment within a given installation.

NOTE 1 Attention is drawn to the European Commission's Guide for the EMC Directive 2004/108/EC [82].

*NOTE 2 For protection of workers from electromagnetic fields, see **4.11.3**. For EMC relating to functional safety, see **13.5.3**.*

Before design for installation of electrical/electronic instrumentation begins, the responsible person who controls the configuration of the installation should be identified, and information on the boundaries and EMC characteristics of the installation obtained.

NOTE 3 The person responsible for the installation, according to the EMC Regulations [21] is "…the person who, by virtue of their ownership or control of the relevant fixed installation, is able to determine that the configuration of the installation is such that when used it complies with the protection requirements…" .

The EMC characteristics of all equipment, whether CE marked or not, should be agreed with the responsible person and main contractor before procurement begins. Equipment should conform to the relevant product standards. Equipment in the scope of BS EN 61010 should meet the requirements of the relevant parts of BS EN 61326. Other product standards are listed in **4.4.4**. Where there are options in the standards, equipment should meet the requirements for the option that is applicable to the installation.

NOTE 4 Instrumentation meeting the emission requirements of the standard may not provide full protection against interference to broadcast receivers when a receiving antenna for industrial or professional applications is within 30 m or a receiving antenna for domestic and commercial applications is within 10 m. Additional mitigation measures might be necessary.

Before installation of all instrumentation, it should be confirmed that it is electromagnetically compatible with other electrical/electronic apparatus installed or intended to be installed in the installation that could be affected by it or that it could affect. Where it is not possible to ensure that all equipment in an installation will operate as intended because of EMC problems then additional mitigation methods might be necessary. These can include restricting the use of radio transmitters or electrically noisy equipment within a certain distance of the apparatus involved or the use of filtering, shielding, overvoltage suppression, galvanic isolation, etc.

Before installation, it should be confirmed that the manufacturer's instructions for installation and use with respect to EMC have been supplied and are available to the installer. It should also be confirmed that the manufacturer's labelling or instructions include information on the class and group of the instrumentation and an explanation of the meaning of class and group. Where the manufacturer's instructions include a restriction on use then unsuitable locations in the installation should be identified.

Before installation of electrical/electronic instrumentation without CE marking, it should be confirmed that the apparatus is suitable for the installation in which it is to be used, and that the accompanying documentation makes a specific reference to the installation.

COMMENTARY ON GOOD ENGINEERING PRACTICE
The European Commission Guide for the EMC Directive 2004/108/EC [82] says that "Good engineering practice comprises suitable technical behaviour by the responsible person, taking account of all relevant recognised standards and codes of practice applicable to the particular fixed installation.

The responsible person should be aware that good engineering practice, particularly in the field of EMC, is in constant evolution. Therefore the responsible person will need to ensure that they employ 'state of the art' practices, i.e. the most modern publications, when seeking to ensure that their fixed installation meets the requirements for protection specified in the EMC Directive."

Electrical/electronic apparatus should be installed in accordance with the manufacturer's instructions and good engineering practice as identified by the person responsible for the installation. Particular care should be taken with cabling and earthing; see BS IEC 61000-5-1 and BS IEC 61000-5-2 respectively for installation and mitigation guidelines. Conflicting requirements should be resolved between the apparatus manufacturer, installer and persons responsible for the EMC performance and electrical safety of the installation.

WARNING. EMC practices and mitigation requirements cannot take priority over electrical safety requirements. Alternative measures might be necessary.

It is recommended that all documentation, EMC characteristics of all apparatus, manufacturers' instructions, installation documentation/ standards complied with, etc., be retained.

9.6 Waste from electrical and electronic equipment (WEEE)

NOTE 1 This clause applies only to equipment that is within the numbered categories set out in Schedule 1 of the Waste Electrical and Electronic Equipment Regulations 2006 [83].

NOTE 2 It is a legal requirement that waste from electrical and electronic equipment is correctly disposed of or recycled at the end of its life. Suppliers have an obligation to take back equipment marked with the symbol in Figure 32. They also have an obligation to take back equipment without the symbol if they are replacing it with like for like, even if the equipment they are replacing is not theirs. All other equipment has to be correctly disposed of by those responsible for the site.

NOTE 3 With the exception of small equipment, or equipment that was placed on the market before the commencement of the regulations, equipment falling within the scope of the Waste Electrical and Electronic Equipment Regulations 2006 [83] is required to be marked with the crossed-out wheeled bin symbol shown in Figure 32.

NOTE 4 The regulations in force, and guidance on them, are regularly reviewed and might vary according to the date of disposal.

NOTE 5 Attention is drawn to the BERR guidance notes on the Waste Electrical and Electronic Equipment Regulations 2006 [84].

There should be a site procedure in place to identify waste electrical and electronic equipment subject to the Waste Electrical and Electronic Equipment Regulations 2006 [83] and to ensure that it is appropriately disposed of.

Figure 32 **Example of electrical and electronic equipment marking**

9.7 Restricted substances

NOTE 1 Attention is drawn to EC Regulation 1907/2006 [85] concerning the registration, evaluation, authorization and restriction of chemicals. This regulation applies both to substances on their own, and to "articles" (such as any electrical or mechanical equipment or components).

NOTE 2 The use of certain substances within articles might be restricted, might need to be registered with the European Chemicals Agency (ECHA), might need to be advised to the recipient, might need to be notified to the ECHA, or might need to be authorized by the European Commission.

NOTE 3 The Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment Regulations 2008 [86] (RoHS Regulations) also restrict the putting on the market of certain electrical and electronic equipment containing more than permitted levels of lead, cadmium, mercury, hexavalent chromium and PBB and PBDE flame retardants. Attention is drawn to the BERR guidelines on the RoHS Regulations [87].

The user should follow any advice or instructions provided by the supplier in respect of any precautions that need to be taken, e.g. with regard to:

- all new instruments and equipment using batteries (ensuring that they contain the correct batteries and that spare/replacement batteries are of the correct type);
- exposure controls/personal protection;
- handling and storage;
- disposal consideration;
- fire-fighting measures;
- transport information.

9.8 Batteries (including battery packs, button cells and accumulators)

*COMMENTARY ON **9.8***
All new batteries, whether or not incorporated into appliances, are now prohibited by law if they contain more than 0.000 5% of mercury (Hg) by weight, except button cells, which can have no more than 2% of mercury by weight. Portable batteries that contain more than 0.002% of cadmium (Cd) by weight are prohibited, unless they are intended for use in emergency and alarm systems, including emergency lighting systems, medical equipment or cordless power tools. With some exceptions, appliances are required to be designed so that batteries can be easily and safely removed. The exceptions are for where safety, performance, medical or data integrity reasons, continuity of power supply is necessary and requires a permanent connection between the appliance and battery. All batteries containing more than 0.000 5% mercury, more than 0.002% cadmium or more than 0.004% lead are required to be marked with the appropriate symbol, Hg, Cd or Pb, unless they are very small, in which case the marking has to be on the packaging. All batteries are required to be separately collected so as to facilitate their treatment and recycling. It is a requirement that batteries are removed from waste electrical and electronic equipment before its disposal.

At the time of publication, regulations are in preparation which will cover all battery-containing equipment and instruments, and the collection/disposal of waste batteries.

Procedures should be in place to ensure that:

- all new instruments and equipment using batteries contain the correct batteries and spare/replacement batteries are of the correct type;
- all battery-containing appliances have manufacturers' instructions for the safe removal of batteries;
- batteries supplied in equipment/instruments and as replacements/spares can be identified.

10 Regulating devices

*COMMENTARY ON CLAUSE **10***
A regulating device is the final control element in a process control loop. The most common type of regulating device is the globe type control valve, although many other types of control valves are currently in use, such as butterfly valves, ball valves, rotary eccentric plug valves, partial ball valves, diaphragm valves, self-acting regulators, sliding or multivane dampers.

Control valves are used to vary the area through which a fluid passes and can be operated by a number of different types of actuator. The most commonly used actuators include spring return pneumatic diaphragms, pneumatic pistons, hydraulic pistons, electric motors, electro hydraulic actuators, solenoids and thermally-actuated valves.

Actuators are used to provide the motive force to operate the valve and the motion can be linear or rotational (part turn or multiturn).

Other types of regulating devices include variable speed drives, variable speed gearboxes, power operated louvres, etc.

10.1 Mechanical protection

Special care and protection should be provided to ensure that control valves are not damaged when being transported and installed.

Flange faces should be protected from mechanical damage. This is especially important where plastics bodied valves are used or where the valve has a lined body.

It can be useful to coat the flange facing of ferrous valves with an easily removed anti-rust compound.

Special care should be taken with lifting equipment to avoid mechanical damage to any of the valve and actuator auxiliary items of equipment, e.g. feedback linkages to external positioners, small bore pipes and pressure gauges.

10.2 Pre-installation checks

10.2.1 Visual inspection

Before a control valve is installed it should be carefully checked to ensure that there is no damage and that it conforms to the original design specification.

The following items should be checked against the valve/actuator data plates:

a) tag number;

b) body rating;

c) body material;

d) flange size, facing and rating;

e) trim size and material;

f) action on supply failure;

g) action for control;

h) auxiliary items.

10.2.2 Performance checks

Performance checks should be carried out to demonstrate that the valve operates correctly for the system specified. These checks should include tests to ensure that:

a) the valve moves accurately and smoothly over its full range;

b) the speed and direction of movement is correct for the application;

c) the valve moves to the correct position in the event of a supply failure.

All control valves requiring tight shut-off should be pressure-tested to ensure that the leakage rate is within the design specification.

The additional tests described in **19.5.14.2**h) should also be carried out.

When the valve and actuator are supplied by different manufacturers, the mechanical fitting of the actuator on to the valve body should be inspected/tested to ensure correct assembly for transmission of maximum actuator power to the valve.

10.2.3 Partial stroke testing (PST)

10.2.3.1 General

Normally energized open/closed valves may be equipped with remotely activated PST due to the location or for reliability purposes. Valves operating as part of a safety-related system may use PST as a means to extend the period between full stroke tests.

The principle is to de-energize the command to the valve such that it starts to close. When the position reaches a set point, the command is re-energized to open the valve. The set point should be reached within a predefined time from the command being de-energized.

The use of SMART positioners can improve fault diagnostics. These include intelligence to provide detailed diagnostics of the movement of the valve, allowing predictive maintenance routines to be applied. PST diagnostics and history may be stored in the positioner's processor, independent of the controlling system.

The quantitative benefits of PST are not clearly defined. The test verifies that a valve will start to close, it does not guarantee full closure. This should be taken into account in relation to the duty of the valve.

Suitable substantiation should be performed prior to applying PST to a specific duty.

10.2.3.2 Test instigation

Requests for PST can be automated or manually instigated. Automated PST should alert plant operators that a test is in process. Manual PST should be recorded by the controlling system or by manual reporting.

10.2.3.3 Test monitoring

PST can only be applied to valves with a stroke time which permits practicable detection and reporting of the valve position and speed of operation. Where position is detected by fixed proximity switches, the switch should be mounted such as not to be liable to movement caused by vibration or impact.

Periodic visual inspection should be performed for the proximity switch position.

SMART positioners may use analogue positional feedback of the valve state. Where the positional detection is not integrated in the positioner, periodic visual inspection of the detection device should be performed.

Suitable access to the positioner should be designed into the installation to permit visual inspection.

10.2.3.4 Test recording

The results of PST should be recorded by the controlling system and held in the system historian.

Failure to complete the PST in the defined time should generate a system alarm.

10.2.3.5 Certification

Positioners with embedded PST used for safety-related functions should be suitably certified in accordance with BS EN 61508 or BS EN 61511 for the integrity level of the process requirement.

10.3 Control valve installations

When designing control valve installations for isolation and bypass, the following recommendations should be met.

a) Isolation valves, bypass valves or handwheels should be installed where necessary in order that control and shut-down valves can be tested and/or maintained while the plant continues production.

b) Each installation should be considered on its own merit and the individual requirements should take the following into account:

   1) frequency of testing or repair;

   2) expected failure mode of control valve;

   3) normal operating procedures for plant running, e.g. continuous or batch;

   4) whether or not the plant can be controlled manually while the control valve is being tested or repaired.

c) When a manual bypass is used, the control valve should be fitted in the straight-through path.

d) Manual isolation valves in series with control valves should be of the line size and should introduce negligible pressure drop or flow disturbance in the fully open position.

e) The bypass valve should be of similar flow capacity to the control valve and should be suitable for fine manual adjustment.

f) Where required, vent or drain valves should be provided adjacent to the control valve together with the provision for flushing and purging. Isolation, bypass and vent valves may be automatically operated.

g) In steam lines the upstream side of the control valve should be adequately provided with steam traps to prevent carry-over of condensate.

10.4 Access for testing and maintenance

In order to ensure that there is adequate access for testing and maintenance, the following recommendations should be met.

a) Control valves should be installed so that they are easily accessible for in situ testing and maintenance from the floor or permanent access platform.

b) Valve position indicators, signal gauges, positioners, etc., should be clearly visible from the floor or permanent access platform.

c) Adequate space should be left above the control valve where lifting equipment is required to remove the valve or actuator for maintenance.

d) Adequate space should be allowed below the control valve to facilitate in situ servicing of the valve internals where access is from the bottom.

e) When thermal insulation is required around a control valve, it should be fitted in such a manner to allow easy removal for control valve maintenance.

f) When a pipeline is heat traced, it might also be necessary to heat trace the control valve to prevent static fluids from solidifying. Heat tracing might be required on a control valve to prevent freezing which could be caused by pressure changes or changes in other process conditions across the control valve, or to prevent condensation in wet gases. The heat tracing should be fitted in such a manner to enable easy removal for control valve maintenance. It should not be capable of providing enough heat to damage components of the control valve under any process and fault conditions.

10.5 Environmental protection

Control valves and auxiliary items should be protected from adverse environmental conditions, such as:

a) excessive heat or cold;

b) corrosion;

c) vibration;

d) falling debris;

e) mechanical damage;

f) leakages from other pipelines or plant items.

Control valves should be installed so that any leakages onto other equipment are minimized, e.g. gland leaks.

In addition to selecting the correct design of control valve for the application, it might be necessary to apply acoustic insulation to the control valve and its associated pipework to reduce the emitted noise level.

10.6 Piping

10.6.1 Control valve installations in process piping

For control valve installations in process piping, the following recommendations should be met.

a) Pipework on either side of the control valve should be permanently supported.

b) When the control valve body is of a smaller nominal size than the line, its connection to the line should be made using taper pieces/reducers.

c) The surface finish on the control valve flange faces should be the same as that on the pipe flange faces. Joint rings, which should be of the correct material, should not protrude into the pipeline.

d) Before installing the control valve, all packaging and protection materials should be removed.

e) If it is desirable to achieve close conformity between valve design conditions and actual valve flow characteristics, the pipe should have no bends or obstructions for five pipe diameters upstream and downstream of the valve, and no sharp bends for ten diameters.

f) Piping should be arranged to allow easy removal and replacement of the control valve and flange jointing materials and, where required, space should be left for in situ replacement of the actuator and trim.

g) Piping runs should be constructed in such a manner that they do not apply excessive stress to control valve bodies. The piping should be built up progressively to include the control valve (or a replacement spool piece), rather than leaving a space for the control valve to be fitted later.

h) Where a control valve has to be welded into a pipeline, special care should be taken to ensure that the maximum temperature of the control valve components is not exceeded during the welding operation.

i) The attitude in which a control valve and its actuator is mounted should be in accordance with the manufacturer's instructions. For high temperature applications it might be preferable to mount the actuator below the pipeline to reduce its temperature.

j) The control valve should be installed so that it is not fitted into a lute in the pipeline.

10.6.2 Protection during pipeline cleaning and testing

If pipelines are to be flushed, steam cleaned or chemically cleaned, control valves should be removed and replaced by spools, unless the materials of the control valve are suitable to withstand the cleaning operation without damage.

During pipeline pressure testing, control valves should be put into the fully open position (or bypassed) to avoid excessive differential pressure across the valve.

10.7 Control valve bodies

10.7.1 General

Different types of control valves might require different arrangements for installation and testing. The installation should conform to the manufacturer's instructions but some specific recommendations for the more commonly used valves are given in **10.7.2** to **10.7.4**.

10.7.2 Globe valves

A globe valve should be installed so that the fluid flows through it in the direction specified by the manufacturer.

NOTE The flow characteristics may be altered if the valve is reversed. The fluid pressure drop across the valve plug can affect the power needed from the actuator to move the valve.

10.7.3 Butterfly valves

Butterfly valves are often supplied as a wafer type of body that is clamped between pipeline flanges.

Care should be taken to avoid damage to the valve body faces and disc during transport and installation, particularly if the disc or body is coated. When a wafer-type valve is fitted with a power-fail open type of actuator, the disc will protrude outside the valve body. The valve should be locked in the closed position or be fitted with short spool pieces on each side to avoid damage during installation.

10.7.4 Ball valves

The torque required to move a ball valve varies with pipeline conditions, e.g. operating pressure and temperature. When testing actuator power and speed, these variations should be taken into account.

10.8 Control valve actuators

10.8.1 Diaphragm actuators

Diaphragm actuators can be used with or without a positioner. The positioner normally requires an air supply that has to be filtered and regulated to the correct pressure. The actuator stem should preferably be mounted in a vertical position.

For high temperature applications it might be preferable to mount the actuator underneath the final control element.

10.8.2 Piston actuators

Piston actuators can be either pneumatic or hydraulic. In each type the fluid pressure can be varied on both sides of a piston attached to the final control element stem or shaft.

The force produced by the actuator depends upon its supply pressure. The actuator should therefore be connected to a supply system that will maintain the pressure for which the actuator was designed.

10.8.3 Power cylinders

Power cylinders are used to provide greater thrust, longer strokes or faster responses than other types of actuators, e.g. as might be required by very large control valves, dampers and louvres. The operating medium may be pneumatic or hydraulic.

If the power cylinder is not coupled directly onto the final control element, linkage between the two should be as direct as possible.

Linkages should be fitted in a manner that minimizes the effects of hysteresis. They should be fitted to allow for any possible movement of the power cylinder relative to the plant pipework and space should be provided to accommodate this movement.

Where movement is transmitted via wire ropes swivels should be fitted.

All connecting mechanisms should be checked for correct alignment.

10.8.4 Electric actuators

Electric motors are sometimes used with a gearbox system to operate control valves. These could be for linear or rotary operation of the final control element.

The electric actuator is normally supplied already fitted to the control valve.

The actuator electrical supply should be checked to ensure the correct voltage and phase rotation.

The motor case should be connected to earth.

All cable entries should be glanded and control circuit housings should be completely sealed.

The gearbox system should be checked to ensure the correct quantity and type of lubricant.

It might be necessary to check/adjust the limit switches on each end of the motor travel and the torque cut-out switch, if fitted.

When putting into service, the position of the handwheel clutch mechanism should be checked.

10.8.5 Smart actuators

*NOTE See **8.1** for recommendations on smart instrumentation.*

A smart actuator incorporates enhanced operational features and diagnostics. Due to the level of diagnostics, such a device is generally connected to the host control system by a digital communication bus.

The motive power for the valve will still be by air, hydraulic or electric force. The integrated actuator control unit may include test functions such as partial stroke and profiling (**10.2.3**) whereby the actuator trajectory is recorded for comparison with a reference. This can be used for predictive maintenance.

Smart actuators may include a separate hardwired connection for emergency operation by a safety system which will overrule the digital control functions.

The recommendations for installation are as for conventional actuators. The communications interface should conform to the applicable protocol standards and fieldbus cable installation standards as described in **15.7**.

10.9 Auxiliary equipment

10.9.1 General

Control valves can be fitted with many additional items to enhance their performance. It is essential for the correct operation of the control system that the auxiliary items are robustly mounted and correctly adjusted in accordance with the manufacturer's instructions.

Advice on the correct installation of some of the auxiliary items commonly used is given in **10.9.2** to **10.9.7**.

10.9.2 Positioners

Control valve positioners may be an integral part of an actuator or an additional item of equipment that is mounted onto the actuator and valve and connected to it via mechanical linkages.

The valve position feedback linkage should be carefully checked to ensure correct fitting and that it is free from mechanical damage.

The operating range of the valve with positioner attached should be checked (see **19.5.14**).

The positioner should be mounted in such a way to enable easy access to indicators and adjustments when the valve is in situ.

10.9.3 Current to pneumatic converters

Current to pneumatic converters should preferably be independently mounted local to the control valve, to enable the valve to be removed for maintenance without disturbing the converter installation and connections, and to avoid the effects of vibration.

10.9.4 Booster relays

Where booster relays are used to improve the response time of control valve actuators, they should be provided with sufficient air supply and venting capacity to ensure stable operation under all conditions.

10.9.5 Position indicators

All control valves should be equipped with an indication of the actual position of the valve, e.g. system position indication.

Where transmitters are used to indicate remotely the position of a control valve, the transmitted signal should be taken as directly as possible from the actual valve position by attachment to the valve stem or shaft.

NOTE 1 Position sensing switches are sometimes used to indicate remotely the position of a control valve, e.g. in an automatic sequencing or shut-down system.

Where the position of a valve is required to be known for safety reasons, i.e. its position is critical to the safety of a reaction or process, the limit switches or proximity devices used should be specified as having the necessary level of integrity as to be suitable for such applications.

NOTE 2 BS EN 60947-5-1 is a suitable standard for limit switches. The manufacturer's advice should be sought as to the suitability of such devices for these applications.

Limit switches should be robustly mounted in a position on the valve in order to monitor as closely as possible the actual valve position. The switch should be mounted on the correct end of the valve travel and adjusted to the correct detecting position in accordance with the manufacturer's instructions.

NOTE 3 The switches mentioned above are usually mechanically-operated position switches or proximity switches.

10.9.6 Manual handwheels

NOTE Special care should be taken when working on or near power-operated valves as these can be set into motion unexpectedly.

When a control valve is fitted with a manual handwheel, clear indications should be given of the following:

a) whether the valve is under manual or automatic control;

b) the position of the valve;

c) the direction of rotation of the handwheel to open the valve.

Manual handwheels should be easily accessible to the operator.

10.9.7 Capacity vessels

NOTE Attention is drawn to the Pressure Equipment Regulations 1999 [18] and the Supply of Machinery (Safety) Regulations 1992 [17], as amended (see Table A.1) in respect of the design and construction of these parts of the system, where such vessels are classified as pressure vessels.

Capacity vessels are sometimes used to assist the air-fail actions of pneumatic actuators.

10.10 Variable speed drive (VSD) systems

*COMMENTARY ON **10.10***
An electronic VSD provides a variable voltage and (for a.c. motors) frequency supply. The most common type of VSD used in process control systems is an a.c. drive, some times referred to as a variable frequency drive or a.c. inverter.

VSDs are most frequently used to control standard "squirrel cage" motors. Standard inverters (using simple open loop control) are used in the majority of VSD applications. High performance drives (often called flux vector drives) are available for applications where torque control dynamics are critical. Other applications might require special features such as precise position control – servomotors and motion control type inverters often achieve this. VSDs are available which can perform the entire range of rotational motion applications, in power ratings ranging from fractional kilowatts to several megawatts.

Many VSDs have communication capabilities that enable information from the drive to be accessed and manipulated remotely over a network, thereby simplifying maintenance and diagnostic procedures.

Benefits from the use of properly specified VSDs can include variable speed, reduced electrical energy, reduced system stress and improved process (output) quality. However, in deciding whether to use VSDs, account has to be taken of the type of motor, the application and whether it is new build or retrofit.

10.10.1 General

The correct selection of drives and their intended use should be established at the installation design stage. Drives are ideally suitable for improving electrical energy efficiency, particularly of pumps, fans and materials handling, or where there is a high usage duty cycle. However, it should be ensured that the intended efficiency improvement is not outweighed by capital and life-cycle costs, or where motor efficiency will be affected to the extent that overall efficiency is reduced. Other ways of improving energy efficiency, such as energy optimizing soft starters or mechanical means, e.g. use of gearboxes and correct selection of chain and belt drives, can be used as alternative options.

NOTE 1 Attention is drawn to the GAMBICA/REMA technical guide Variable speed drives and motors – installation guidelines for power drive systems [88], and the Gambica technical guide CE marking and technical standardisation – Guidelines for application to electrical power drive systems [89].

NOTE 2 If an energy optimizer works then the motor is too big, and a smaller motor might be needed.

Before installation, it should be confirmed that the equipment is suitable for the electromagnetic environment of the site location.

*NOTE 3 Attention is drawn to the EMC Regulations [21] (see **9.5**) in respect of drive systems. Drives meeting the requirements of BS EN 61800-3 are expected to meet the requirements of the legislation, if the correct category has been selected.*

A drive may be supplied as:

- a basic drive module (BDM) – a stand-alone converter unit without any other components;
- a complete drive module (CDM) – a BDM plus system controls and directly connected options;
- a power drive system (PDS) – the user/system integrator may combine a BDM, CDM, motor and other components to become a PDS.

BDMs and CDMs should conform to BS EN 61800-5-1 or BS EN 50178. If the PDS is part of a machine then it should be confirmed that an appropriate declaration has been obtained from the machine manufacturer before the machine is installed.

*NOTE 4 Attention is drawn to the Electrical Equipment (Safety) Regulations 1994 [16] (see **4.4.4**). Electrical aspects of PDSs conforming to BS EN 61800-5-1 or BS EN 50178 and/or BS EN 60204-1 are expected to meet the requirements of the legislation.*

The drive module should be rated to provide a continuous current output at least equal to the maximum current drawn by the load over the operating cycle, but where the load exhibits short or occasional torque peaks, use may be made of the short-term peak capability of the drive.

In deciding the installation location for the drive, account should be taken of altitude, ambient temperature, humidity, possibility of condensation, ventilation access, vibration, airborne contamination, noise and electrical power quality.

10.10.2 Mechanical installation

10.10.2.1 General

Drives can be supplied for machine, wall or floor mounting, or as modules for enclosure, panel or cubicle mounting in a plant or control room.

a) For machine-mounted drives where high levels of vibration are likely to be encountered, vibration damping mounts can be useful.

b) Walls should be brick or block construction for wall-mounted drives.

NOTE Most drives are supplied with a minimum rating of IP20, but drive modules may be to IP00, and drives to IP54 are common.

It is essential to protect drives from condensation and corrosive gaseous contaminants, such as hydrogen sulphide, whilst ensuring that cooling requirements (see **10.10.2.2**) can be achieved. The appropriate ingress protection commensurate with safety and environmental requirements should be selected.

Most drives operate at a maximum ambient temperature of 40 °C. Above this and below 3 °C, the manufacturer's recommendations should be followed.

Where large drives are to have their discharge ducted to outside air, care should be taken to ensure that there is no formation of condensation in the ducting. Anti-condensation heaters should be used where necessary.

Where drives are to be installed in unheated locations, such as switch rooms, or are likely to be switched off for long periods, means should be established to clear condensation before applying power. Anti-condensation equipment should be used where necessary.

10.10.2.2 Cooling

Cooling requirements should be established at the installation design stage, taking into account:

- converter heat dissipation;
- converter air flow (the majority of converter modules are force ventilated);
- distance from other equipment;
- heat produced by other equipment in the same enclosure;
- average temperature;
- ambient conditions surrounding the enclosure;
- the size of the enclosure;
- the overall heat dissipation area of the enclosure.

For protection against condensation, a converter enclosure should be kept at 10 K above ambient. Heaters might be needed if free ventilation is required.

Heat loss data for the converter should be obtained from the manufacturer. If the data is not available, heat loss should be taken as 3% of the controlled motor power.

Where drives are wall- and/or floor-mounted, the free surface area of the enclosure should only be taken into account when establishing heat dissipation through the enclosure walls.

When enclosure walls have insufficient surface area to dissipate the heat, forced cooling should be installed. The airflow rate should be $W \times k$ m^3/ hour, where W is the non-dissipated heat in watts and k is a constant (0.31 for air at sea-level if a 10 K differential is to be maintained).

Care needs to be taken to ensure that there is no re-circulation of the heated exhaust air. If free ventilation is required, the cross-sectional area of the outlet should be at least 20% greater than the inlet.

Flameproof motors with type D protection should not be installed with variable speed drives.

10.10.3 Electrical installation

WARNING. Do not apply power to a drive without understanding the instructions for safe installation and use. Due to capacitor storage, an electric shock is possible after power has been removed. Power and charge indicators should indicate that power is off and that there is no unsafe charge before the internal parts of a drive are touched.

10.10.3.1 General

Installation should be in accordance with the manufacturer's installation instructions and BS 7671.

Before installation, it should be verified that the supply voltage and tolerances match the drive input voltage specification.

CAUTION. Before mains are applied to any converter, it should be confirmed that the supply has not been inadvertently connected to its motor terminals. The installation could be seriously damaged.

Where multiple drives are being installed, consideration should be given to connecting them to their own supply transformer. Some high power drives, using 12 or more pulse rectifiers, require a power transformer.

NOTE 1 All converters have a three-phase output to the motor.

Drives may have a single-phase or three-phase supply. Before applying power to a single-phase supply drive it should be confirmed that only a single-phase supply is connected to it. Where drives with single-phase inputs are used on three-phase supplies, care should be taken in sizing the neutral conductor if it is to be connected, because of the heating effect of harmonic currents. Consideration should be given to sizing the neutral conductor to carry three times the phase current. This does not apply when using drives with three-phase supplies.

Normal drives with EMC filters should be connected to TN-S systems. Connection to TN-C systems is not recommended. EMC filters should not be used when connecting to IT networks.

Converter supply inputs should be protected by a fuse, MCCB or MCB. Some designs require special, fast-acting semiconductor fuses. In this case it is generally not possible to use a MCCB.

Where high-speed fuses are used to protect the PDS, consideration should be given to using lower rated slow fuses to protect the supply cables.

NOTE 2 Further information on selection of RCDs in given in BS EN 61800-5-1.

For protection of personnel, conventional protective bonding is recommended. RCDs do not protect against all faults, but if disconnection is by RCDs they should be Type B. Type AC RCDs should never be used with drives.

WARNING. Due to the presence of large capacitors in the d.c. link of most converters, the use of an RCD does not remove all sources of electrical charge in a drive system. Power and charge indicators should indicate that power is off and that there is no unsafe stored charge before the internal parts of a drive are touched.

CAUTION. Care should be exercised when utilizing an RCD upstream of a drive.

10.10.3.2 Electromagnetic compatibility EMC

NOTE 1 In order to comply with regulations and to provide compatibility with other equipment within a control panel, it is essential to establish a good RF reference plane.

NOTE 2 Drives generally require input EMC filtering to conform to EMC Regulations [21]. Some low power drives can be supplied with built-in filters, otherwise manufacturers are required to provide information on the filter requirements.

The reference plane should have very low impedance over the frequency range to be protected against. All circuits and cable runs and connections to them should be physically as close to it as possible. This includes cable screens; they should not be terminated at the input to the enclosure.

Before installation, it should be confirmed that the filter information is available and the correct filters have been procured.

Filters and drives should be mounted on the RF reference plane with direct metal-to-metal contact (any paint removed). The filter should be mounted as close as possible to the power input terminals of the drive, so that the cable connection is as short as possible.

Filters, drives, MCCBs and braking units should be located as far away as possible from other instrumentation and control equipment. Consideration should be given to using control transformers with an inter-winding earth shield to decouple drives from the other instrumentation and control equipment.

Power, signal and control cables should be screened. Motor cables should be shielded with braid or armour and be correctly earthed. All cable screens and armour should be earthed at both ends using 360° clamping arrangements. In the drive enclosure they should be connected to the RF reference plane with direct metal-to-metal contact (with any paint removed).

Where there is concern about circulating currents due to earthing screens and armour at both ends, consideration should be given to potential equalizing conductors in parallel with the cables.

All unused conductors should be earthed at both ends.

Segregation should be maintained between cables (see **15.13**), particularly between the motor cable and all other cables.

Intermediate cable connection joints between a secondary enclosure and a drive should be avoided.

Drives are generally not capable of regenerative operation, so braking resistors should be fitted where energy might be returned from the load, e.g. for deceleration of a high-inertia load or "windmilling" fan. To size the resistor, the minimum permitted resistance value, maximum voltage on the resistor and maximum instantaneous values should be obtained from the drive manufacturer: the resistor will also have maximum energy and maximum continuous power ratings. It is recommended that thermal protection be fitted to the brake resistor and the supply is disconnected if a fault results in continuous power dissipation in the resistor.

It is recommended that the inverter be inhibited before output switching.

10.10.3.3 Cables

NOTE Attention is drawn to the EMC Regulations [21].

Power supply cables can be chosen to suit the installation, but drive output cables should always be multi-core types, paralleled to achieve current rating if necessary.

Drives are sensitive to the capacitance of output cables. Cables with abnormally high capacitance, e.g. mineral insulated types, should be avoided where possible. The drive manufacturer should be consulted for special requirements or for lengths exceeding 50 m.

Drive output cable screens should have low impedance to RF. They should have good electrical continuity along the cable length, with coverage as close as possible to 100%. Braided or helical constructions should be such that current can easily pass from turn to turn along the length.

Four-core shielded cables can be used for drive output cabling, but, for larger cables, consideration should be given to cables with a symmetrical construction, where either there should be no internal protective conductor or there should be three internal protective conductors, symmetrically arranged with respect to the phase conductors. It is essential that the manufacturer's installation instructions be followed.

It is a requirement for machinery to have an emergency stop button. The Faraday Cage established round the PDS should be continued round the casing of the emergency stop.

10.10.3.4 Earthing and bonding

All conducting parts of PDS frames should be earthed in accordance with BS 7671.

NOTE 1 For EMC purposes, equipotential bonding of PDS parts has to be effective over a wide frequency range, requiring low conductance conductors of at least one tenth of the phase conductor. The equipotential bonding conductors need to meet the requirements for EMC in addition to the requirements of BS 7671.

NOTE 2 Further information is given in BS EN 60204-1.

NOTE 3 If the cable screen is used as a protective earth conductor then for safety reasons it has to meet the requirements of BS 7671 and have a conductance of at least 50% of that of the phase conductor. If a separate protective conductor is required then for EMC reasons it has to be either entirely outside the screen, or else entirely inside the screen and terminated by a very short connection at the same place as the screen at both ends of the cable.

10.10.3.5 Power factor correction

> **CAUTION.** Power factor correction capacitors should not be connected between a converter and motor. Damage to the installation could result.

Drives have a displacement factor (cosϕ) of close to 1, and do not require power factor correction.

Drives generate input current harmonics, and where a substantial part of the load on a power system comprises drives, harmonic mitigation measures might be required. There is a risk of harmonic resonance if power factor correction capacitors are connected to the same low voltage supply as drives. If capacitors are necessary then they should be fitted with de-tuning reactors.

11 Pneumatic and hydraulic supply systems

*COMMENTARY ON CLAUSE **11***
The correct design and installation of a power supply system is essential to ensure plant operation and reliability. Errors in the installation of a power supply system can render the most well-designed control system partly or totally ineffective.

Non-electrical power supply systems generally used for instrumentation systems and regulating devices fall into two main categories:

- *pneumatic;*
- *hydraulic.*

*Guidance on electrical supply systems is given in Clause **17**.*

In general, the word "pneumatic" used in this clause refers to air; however, if other operating media, e.g. process gases which might be flammable or toxic, are used, special precautions will be necessary (see IEC/TR 61081).

11.1 General

All pneumatic and hydraulic supply systems supporting safety functions should be assessed to ensure that the appropriate level of integrity is maintained for the safety system.

11.2 Pneumatic supply systems

11.2.1 Quality and operating pressure

Compressed air or gas used for supplies to instrument and control systems should be dry, clean and oil-free and, in the case of air, should conform to at least the following recommendations, together with any additional recommendations supplied by the manufacturer.

a) The dew point at operating pressure should be at least 10 °C lower than the minimum anticipated temperature.

b) The air should not contain dust particles larger than 3 μm.

c) The air should not contain more than 1 ppm (part per million) mass/mass of oil at 20 °C with the system pressure at 6 bar [3].

Instrument air should also be free of all corrosive contaminants and hazardous gases, flammable or toxic, which could be drawn into the compressor air intake. If the possibility of contamination exists, the air should either be taken from a remote or elevated clean location or be suitably processed.

The supply pressure in the plant instrument air header should be suitable to meet the requirements of the control system, usually 6 bar to 7 bar, or should be at least 2 bar above the maximum operating pressure required by any item of instrumentation equipment.

The air supply system should be designed to maintain an uninterrupted supply for a predetermined time period (see **11.2.4**).

11.2.2 System duplication

Air compressors supplying instrument air should have back-up facilities for reliability, by one of the following:

a) a dual compressor system; or

b) a standby compressor powered from a different source, e.g. steam or diesel power; or

c) a cross-over link with the plant air system, which should be suitably conditioned to conform to **11.2.1**a) to **11.2.1**c) but which will not permit instrument air to be lost to the plant air system.

Where two compressors are used, the system should be designed such that either compressor can be isolated for maintenance whilst the other is operating.

11.2.3 Instrument air compressors

The output capacity of a compressor should be at least 150% of the total instrument air consumption.

Compressors should be suitable for continuous operation, but the design of the compressor/receiver system should ideally be such that the compressor is on load for approximately 50% of its time in order to increase the long-term reliability of the system and reduce the maintenance costs.

The compressor should be capable of delivering air at approximately 2 bar [4] above the air header normal working pressure.

NOTE 1 This is necessary to allow for the pressure drop through the conditioning system, i.e. coolers, dryers, filters, etc.

Compressors should preferably be of the oil-free type, but the lubricated type may be used (sometimes necessary on larger systems) provided that the final air quality conforms to **11.2.1**a) to **11.2.1**c).

A compressor should be supplied with an after cooler and separator to remove most of the free water from the compressed air, and thereby reduce the burden on the dryers.

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3) 1 bar = 10^5 N/m^2 = 100 kPa.

4) 1 bar = 10^5 N/m^2 = 100 kPa.

NOTE 2 Continuously running compressors are usually controlled by automatic unloading systems.

On stop/start compressor systems, a pressure sensor should be fitted that controls the duty cycle and hence the receiver pressure. A further pressure sensor on the receiver should be included to initiate automatic starting of the standby compressor. Pressure sensors used for automatic control purposes should not be used for alarm indication. Separate sensors, each with its own isolating valves, should be provided for alarm purposes when required.

Facilities should be provided to ensure that cooling water does not flow unnecessarily when compressors are on standby or are shut-down.

The noise generated by the compressors should be taken into account, and acoustic treatment applied if necessary to meet the environmental requirements of the plant.

11.2.4 Air receivers

For small systems the air receiver is usually integral with the compressor, whereas on larger systems it is usual to employ one receiver served by two compressors. Facilities should be provided to ensure that the receiver remains in service when either compressor is removed for service.

The total air receiver capacity should be sufficient to provide air at an adequately high pressure to ensure continuous operation of the instrumentation for a period of at least 30 min after compressor failure, or after failure of both compressors on a dual compressor system.

11.2.5 Air dryers

Air dryers should be of the adsorptive type, except for very mild climates where the lowest ambient temperature is not likely to be below 10 °C, when a refrigerant type may be used.

NOTE Most systems are designed for automatic regeneration on a time-cycle basis, usually 8 h, but may be automatically initiated by a dew-point detecting device.

Adsorptive type dryers may be of the heat-less or heat-regenerated type, and facilities should be provided for automatic regeneration of the desiccant without interruption of the dry air supply.

11.2.6 Filters

Air filters, which should be provided at both compressor inlet (intake filters) and after the dryers (after filters), should:

a) have a high separating capacity;

b) have a good accumulating ability, i.e. they should be able to collect a large quantity of impurities without any significant decrease in performance;

c) have a low resistance to air flow.

Intake filters are primarily to remove foreign particles and moisture from the incoming air. They should be carefully positioned to give maximum protection from dust intake and weather conditions, e.g. wind, rain and snow. They should also be easily accessible for maintenance and inspection.

The after filters should be capable of removing dust down to a particle size of 3 μm.

Oil adsorbers should be fitted if the valves of the compressor are lubricated, and should be fitted after the compressor and before the dryer.

11.2.7 Cooling water

*COMMENTARY ON **11.2.7***
Instrument air compressors are often water cooled. The cooling water is usually initiated by solenoid valves and the flow detected by flow switches which in turn may initiate alarms on low flow or trip the compressor on failure. In addition, temperature switches in the water circuit may be used to detect abnormal flow.

Where compressors might be exposed to freezing winter conditions, the cooling water circuits should be heat traced and lagged, especially in systems with 100% standby, i.e. at least one compressor normally not running.

Attention should be paid to the integrity and reliability of the complete cooling water circuit since its loss is the most likely cause of losing all instrument air pressure.

Filters should be installed at some point in the cooling water circuit to prevent the deposition of scale, etc. in the compressor cooling surfaces. They should be of twin design and should be readily accessible for changeover and cleaning.

11.2.8 Valves

Isolating valves should be provided in the installation to ensure that all sections of the air supply system can be isolated for maintenance without interrupting the plant operation. In addition, individual isolating valves should be provided for each instrument requiring an air supply.

All valves should be easily accessible and capable of tight shut-off, and should have a low flow resistance.

Changeover valves for diverting air services from one dryer to another should preferably be of the ball-valve type.

Where ambient temperatures below freezing are expected, consideration should be given to heat tracing the valves and pipework up to the dryer inlet.

11.2.9 Pipework

The design of air supply piping and the sizing of air headers should be in accordance with **14.2**. After fabrication, air supply piping should be degreased, pressure tested, blown out and sealed until required for service.

11.2.10 Pre-commissioning checks

11.2.10.1 Compressors

The manufacturer's pre-start checks and the start-up procedures should be followed. Small-bore pipes and capillaries, etc., associated with compressors should be checked for leaks or physical damage.

Measuring instruments, pressure and flow switches, etc., should be checked for calibration and settings in accordance with Clause **19** and the compressor manufacturer's instructions.

All control systems should be checked for correct operation.

11.2.10.2 Cooling water circuits

The action and setting of pressure and flow switches and interlocks should be checked for correct operation.

Visual flow indicators should be checked to ensure that they function correctly.

The complete circuits should be checked for leaks.

11.2.10.3 Air dryers

Heated dryers should undergo thorough electrical checks.

Heatless dryers should be checked for correct flow of purge air.

The changeover control system should be checked for correct operation.

11.2.10.4 Air piping and valves

All air lines should be checked for leaks (see Clause **20**).

All isolating valves and check-valves should be checked for correct operation.

All instruments connected to an air distribution system should be adequately protected by isolation during initial compressor and piping checks.

11.3 Hydraulic supply systems

*COMMENTARY ON **11.3***
Hydraulic systems are generally supplied as purpose-built power packs but may be custom-built to a specialized design. The basis of most circulating hydraulic systems is one or more pumps, an oil reservoir, accumulator and actuators. The accumulator is pressurized with hydraulic fluid by the pumps. The fluid then flows from the accumulator to the actuators as required and returns to the reservoir on a circulatory system.

11.3.1 General

The manufacturer of a hydraulic system should be consulted to obtain guidelines for design and installation of the system, as there are numerous variations in the features available, including:

a) types of hydraulic fluid;

b) pressure and flow requirements;

c) speed of response;

d) power supplies;

e) standby or back-up systems;

f) shut-down action.

11.3.2 Hydraulic fluid

COMMENTARY ON 11.3.2
Hydraulic fluid is of the following types.

- *Conventional mineral oil. This has the advantage of low toxicity but it is a fire risk, particularly at high pressure.*
- *Synthetic phosphate ester fluids. These have the properties of resistance to fire but can produce toxic fumes when leaks spray on to surfaces at high temperature.*

The fluid should have a high viscosity index so as to minimize the effects of temperature. Heating should be provided if necessary to maintain the viscosity of phosphate ester fluids at low temperatures (e.g.10 °C).

The fluid, a-rings, gaskets and seals of the hydraulic system should be mutually compatible.

The fluid might have, depending on the specification, biocidal additives, viscosity index improvers, oxidation inhibitors, corrosion and rust inhibitors, metal deactivators, anti-wear and load carrying agents, foam inhibitors and colouring agents.

11.3.3 Reservoir

*COMMENTARY ON **11.3.3***
The reservoir performs the following functions:

- *it serves as a storage container;*
- *it dissipates the heat generated in the system;*
- *it assists the settlement of solids or contaminants;*
- *it removes entrained air.*

The reservoir should be designed to hold, between the normal high and the normal low level, sufficient hydraulic fluid to fill the remainder of the system.

The reservoir should be located at the highest point in the system to minimize air locks but should be readily accessible. Sufficient vents should be provided at high points to enable the removal of air locks.

Inert gas blanketing of the reservoir should be provided to exclude air and thereby to reduce corrosion and prevent a hazardous condition occurring with a combustible hydraulic fluid.

If gas blanketing is not used, a permanently open vent should be provided in order to vent gases dissolved in the hydraulic fluid which will be released in the reservoir.

Before filling the reservoir the interior should be completely free from foreign matter.

11.3.4 Accumulator

The system operating pressure is normally maintained by an accumulator in which an inert gas under pressure is separated from the hydraulic fluid by a membrane or piston. The minimum pressure in the accumulator should be not less than that required to operate any actuator against its maximum load at the required speed, taking into account all pressure losses in the system due to friction, etc.

The volume above the high level should be sufficient to empty the drum down to its low level without allowing the system pressure to drop below the minimum operating pressure.

The volume between the high and low level should be sufficient to allow normal operation without exceeding these limits.

The volume below the low level should store sufficient fluid to move all actuators in the system two full strokes or one full cycle.

Gas pressure-type accumulators should conform to PD 5500 and should be provided with a suitable safety valve.

11.3.5 Pumps

The normal means of moving the hydraulic fluid round the system is by a pump (or pumps) designed for normal operating flow and pressure. The pump should be capable of passing the flow necessary for the normal requirements of all actuators operating simultaneously plus 200% of the anticipated leakage.

A standby pump should be provided, preferably lowered from a different source from the main pump.

In the event of total pump failure, the accumulator volume should be sufficient to move all actuators to a safe position.

11.3.6 Filters

Although the system should be thoroughly cleaned before commissioning, filters should be used at strategic points in the hydraulic system to remove foreign matter that might occur due to scaling, etc.

Filters should preferably be the dual pattern in order to facilitate cleaning without interruption of the system operation.

As a minimum, suitable filters should be installed in the pump inlets, the supply line to actuators and the return line from actuators.

11.3.7 Piping

The use of stainless steel tubing is preferable on hydraulic systems in order to minimize scale formation.

Tubing or piping should be sized according to the requirements of the actuators under emergency conditions.

Rigid piping should be firmly clamped to minimize the effects of hammer or vibration.

11.3.8 Flexible hoses

Flexible hoses should be provided on actuators to allow relative movements of components and to minimize vibration.

The minimum bending radii recommended by the tubing manufacturer should be observed to prevent distortion and subsequent failure.

Where there is a potential fire risk, hoses should be of corrugated stainless steel, welded to steel unions or flanges.

When installing flexible hoses, a minimum straight length equivalent to twice the outside diameter of the hose, but not less than 25 mm, should be maintained adjacent to each end fitting.

Torsional loads should not be transmitted to flexible hose because they can damage the hose or end fittings. Similarly, tensile loads should be prevented.

The length of hose should be chosen such that it is not so short that tensile loads are applied, nor should it be so long that excessive sagging results.

Elbow couplings, when used, should be fixed to ensure correct alignment of the hose and so avoid side load distortion.

12 Safety-related instrumentation

*COMMENTARY ON CLAUSE **12***
The recommendations in this clause are intended to enable the safety integrity levels (SIL), as specified by the project safety requirements specification (SRS), for each safety function to be maintained, during installation design, procurement, installation implementation, commissioning, installation modification and installation decommissioning.

12.1 General safety compliance

*COMMENTARY ON **12.1***
BS EN 61508 introduces the concept of Safety Integrity Level (SIL) to incorporate pipe-to-pipe considerations, thereby including field devices such as transmitters, switches and actuators. Field-mounted device installation design is not included in BS EN 61508, however the lifecycle performance of a device in a safety application is influenced by the design installation and testing capabilities.

For new equipment procured after 2004, components and subsystems selected for use as part of a safety instrumented system for SIL 1 to SIL 3 applications should be in accordance with either BS EN 61508-2 and BS EN 61508-3, as appropriate, or BS EN 61511-1:2004, **11.4** and **11.5.3** to **11.5.6** (BS IEC 61513 for the nuclear sector) as appropriate.

Where systems designed/installed before publication of BS EN 61508 are to be used in new projects (legacy systems), or existing systems are to be upgraded, there should be a review with the owner/operator to establish their functional safety characteristics and how they were assessed. The review should be conducted in accordance with the management system requirements of BS EN 61511 to ensure current best practice.

Instruments intended for use in safety-related functions should be supplied with documentation containing the safety parameters that will enable the system designer to assess their suitability for use in the safety instrumented system. This documentation should be retained.

NOTE 1 BS EN 61326-3-1 and BS EN 61326-3-2 give immunity levels for functional safety in general industrial applications and applications with a specified electromagnetic environment respectively. However, safety-related equipment and systems should be procured to meet the requirements of the specific SRS. In some cases, the requirements in these standards might not be adequate and in others they might be excessive.

NOTE 2 The SIL for each safety function in association with the field equipment used will define the level of field equipment redundancy and survivability on each safety loop. This may be simplex (no redundancy), dual, triple, quad, or multiple with m out of n voting implemented.

Safety-related systems should have sufficient immunity against electromagnetic phenomena to maintain the safety function. Immunity requirements are site/application-specific and requirements should be detailed in the SRS. DD IEC/TS 61000-1-2 gives a methodology for the achievement of functional safety of electrical/electronic/programmable electronic safety-related systems, installations and equipment therein with regard to electromagnetic phenomena.

All supporting reports, installation instructions and operating manuals should be adhered to, taking into account any restrictions for use. A safety lifecycle should be developed as described in BS EN 61511.

NOTE 3 Accredited conformity assessment schemes, such as CASS, might be of assistance to demonstrate overall compliance to the standards. Users of this British Standard are advised to consider their use at the initial design stage and before procurement begins.

BS EN 61508 and BS EN 61511 do not mandate the need for certification of competency of personnel, nor for the certification of products, sub-systems, or installations, but they do require that there is adequate and appropriate evidence to support the choices made when selecting suppliers and sub-contractors and in the design and operation of safety-related systems. To collate and validate that evidence, from procedural safety management and competency aspects through to product assessment, requires an experienced and wide-ranging assessment capability.

COMMENTARY ON CONFORMITY ASSESSMENT
It is recognized that relevant good practice, such as contained in HSE Approved Codes of Practice and Guidance, together with relevant standards properly applied within their scope, can play an important role in the achievement of good health and safety performance. In the context of functional safety of electrical/ electronic/programmable electronic (E/E/PE) safety-related systems, BS EN 61508 is such a reference standard for determining whether a reasonably practicable level of safety has been achieved. Sector standards and specific industry standards or guidelines can also form relevant good practice.

HSE believes that, in general, accredited conformity assessment schemes when properly applied, as part of a systematic approach to the management of health and safety risks, can assist duty holders and can be helpful in targeting regulatory activity.

Accredited certification schemes such as CASS (Conformity Assessment for Safety-related Systems), when properly applied and as part of a systematic approach, can help duty holders in making a demonstration that the functional safety of E/E/PE safety-related systems has been properly addressed. In the context of regulatory regimes where safety cases are required, the adoption of schemes such as CASS could provide useful evidence as part of the demonstration that risks have been reduced as low as reasonably practicable (ALARP).

12.2 Installation and commissioning planning

12.2.1 General

An installation and commissioning plan for the safety-related instrumentation should be developed, as it forms an integral part of the safety system life cycle.

The installation and commissioning of safety-related instrumentation should conform to BS EN 61508-1:2002, **7.9**, **7.13** and **7.14**, and/or BS EN 61511-1:2004, Clauses **14** and **15**.

12.2.2 Safety logs

A safety log should be kept throughout the installation and commissioning activities where all deviations from the safety plan are logged with any other safety issues encountered.

12.2.3 Safety reviews

The installation and commissioning safety plan should include regular safety reviews where all reported discrepancies, deviations and issues are analysed, resolved or where necessary reported upwards to the relevant authority. All safety reviews should be fully documented.

12.2.4 Control and safety instrumentation segregation

The SIL of the control system should not compromise the SIL rating of the safety system.

Where the control system has a lower SIL than the safety system, the safety system should be segregated from the control system in all aspects (field equipment, cabling, piping, terminations, system cabinets, system power supplies and distribution).

Where segregation cannot be implemented, then the non-segregated functions should be designed to meet either the safety or the control SIL requirements, whichever is the greater.

The instrumentation installation and commissioning design should ensure that the required separation and isolation between the control and safety systems are maintained.

NOTE "Separation and isolation" refers to the personnel responsible for the design as well as the hardware and software.

12.3 Safety function proof testing

The installation should be designed to support periodic proof testing as defined in BS EN 61511.

To enable the specified SILs of each safety function to be met, a regular safety function proof test should be performed. The specific frequency of the proof test for each safety function should be related, but not limited, to:

- the SIL specified;
- the proven reliability of the equipment in the safety function loop;
- the comprehensiveness and rate of the online diagnostics provided.

The installation of all parts of the safety system, inclusive of instrumentation, should accommodate the specified full function proof testing.

12.4 Redundancy

Where instrument redundancy is implemented, then the installation should be such that it eliminates or minimizes common cause failure possibilities. This may be achieved by location, segregation or other means.

12.5 Cabling and piping

12.5.1 Segregation

Where practicable, all safety-related instrument cabling and piping should be segregated from all control-related cabling and piping to prevent or minimize common cause failure from affecting the integrity of the safety system. Where this is not practicable, the control system cabling and piping should be designed so as not to lower the safety integrity of the safety system.

12.5.2 Redundancy

Where redundancy is specified in the field equipment for a safety loop and/or system power supplies, the routing of the redundant paths of the cabling or piping should follow diverse paths where practicable to do so.

12.5.3 Survivability

The installation design for cabling and piping should take into account the optimum routing for survivability of identified potential hazards.

12.6 Identification

All equipment required to implement a safety function should be clearly identified as safety-related.

13 Control room, associated equipment rooms and electronic systems

13.1 General

Control room systems should be installed generally in accordance with the relevant recommendations given in other clauses. However, because of the nature of these systems, additional procedures are necessary. Examples of such systems are distributed control systems, process control computers, shared-display control systems, programmable multi-loop controllers, programmable logic controllers, alarm systems, programmable electronic safety systems and computer-based data loggers.

This type of equipment is not always designed for industrial usage, but for a control or equipment room environment.

Account should be taken of the access requirements for the delivery of control room equipment. Safe access through construction or operational areas should be identified and controlled through the use of risk assessment and method statements. Plant and control room design should allow for the manual handling to maintain or replace equipment for the lifetime of the plant.

On arrival at site, all packaging should be visually inspected for any signs of damage. Any damaged packaging should be opened in the presence of either the supplier or the haulage contractor.

It is recommended that all markings and labelling pertinent to equipment compliance or legislation should be recorded for future reference.

Crates containing computer equipment should not be opened until a suitable environment can be guaranteed (see **13.2**).

Where practicable, all major movements of the equipment should be completed before the crates are opened.

Crates should be lifted in accordance with the manufacturer's recommendations.

Particular attention should be paid to any warnings displayed on crates such as "fragile", "delicate" or "handle with care"; this is important because some electronic system components are very susceptible to mechanical shock and could sustain damage. Any such crates should be handled with extreme care.

All packaging should be disposed of appropriately.

13.2 Location and environment

13.2.1 General

Electronic systems are susceptible to the effects of adverse environmental conditions such as exposure to moisture, chemical attack and dirt. Therefore, particular attention should be paid to the operating environment if their long-term reliable operation is to be assured. The manufacturer's instructions should be followed during installation.

Atmospheric contamination and limitations on ambient conditions should not exceed the limits specified by the manufacturer. In general this means that equipment rooms should be completed before the equipment is moved to the room and unpacked. Concrete surfaces below false floors and above false ceilings should be sealed before the room can be considered as being completed.

Maintenance of a suitable operating environment might necessitate the installation of air conditioning, positive pressure or ventilation systems, and it should be confirmed that these systems perform as required before control room equipment is installed. They should be designed so that the operational requirements of the equipment are not exceeded, particularly with reference to operating temperatures and relative humidity.

Care should be taken to ensure that no item of equipment is exposed to direct or indirect sunlight, which can cause severe local heating problems.

13.2.2 Air conditioning

In installations where the pressurizing air is unfiltered, a check should be made to ensure that the siting of the intake is such that the ingress of contaminated air will not occur. If the pressurizing air is to be taken from a contaminated area then a check should be made with the supplier to ensure that the correct filters have been fitted to the ventilation system.

Before the equipment is moved into the room, a test should be made to ensure that the air conditioning or ventilation system is capable of dissipating the maximum heat generated by the equipment. This may be done by running portable heaters whose total combined power output is equal to that of the total heat generated by the system in the computer room, and monitoring the temperature at strategic locations. If time is available, this test should be run over a period of several days in order to confirm the reliability of the air conditioning/ventilation system under continuous operation. For the tests to be effective, correct allowances should be made for possible variations in ambient conditions.

During the test, the relative humidity in the computer room should be checked in order to ensure that the equipment operating environment conforms to the manufacturer's specification.

13.2.3 Ventilated environments

In many applications, small dedicated systems such as programmable logic controllers or certain elements of larger systems may be installed on panels, in closed cubicles or in wall-mounted enclosures.

Such equipment is normally designed not to require full air conditioning. However, care should be taken to ensure that adequate ventilation is provided, particularly in the case of closed cubicles and wall-mounted enclosures. Additionally, in dusty or dirty environments, incoming air should be filtered to prevent fans and heat sinks being rendered ineffective.

In damp environments, particular attention should be paid to the seals on doors and covers in order to ensure that they are able to prevent any ingress of moisture.

Atmospheric contamination and limitations on ambient conditions such as temperature and humidity should not exceed the limits specified by the manufacturer.

13.2.4 Vibration

Equipment should not be mounted in an area where it could be subjected to excessive vibration. Where this is unavoidable, permissible vibration levels should be obtained from the manufacturer.

13.2.5 Electromagnetic and radio frequency effects

The manufacturer's instructions should be followed with regard to the susceptibility of equipment to electromagnetic or radiofrequency effects.

Particular attention should be given to the positioning of equipment that could be susceptible to interference of this type.

13.2.6 Video equipment location

Where human–machine interface (HMI) displays are used, these should be located away from strong magnetic fields as such fields can severely distort the displayed image. Although this is not normally a problem in computer and control rooms, it can be in the case of field-mounted terminals, and care should be taken over their location.

13.2.7 Lighting

NOTE Attention is drawn to the Health and Safety (Display Screen Equipment) Regulations 1992 [54], as amended (see Table A.1).

Lighting should meet the ergonomic requirements of the control or equipment room.

Particular care should be taken to ensure that lighting arrangements do not reduce the visibility of any display units. The optimum position will vary depending on the design and type of display unit, but in general the unit should be positioned such that the incident light from other sources does not make it difficult to read.

The positioning of lighting units should be such as to allow maintenance staff to have access without having to climb on to the control equipment.

When selecting the optimum location of display units, care should be taken to avoid the possibility of sunlight falling on to any displays.

13.2.8 Maintenance access

The design of control and equipment rooms should provide adequate access for inspection and maintenance purposes. Particular attention should be paid to the provision of power outlets to be located close to the major hardware items in order that power for the test equipment can be provided safely and conveniently.

Panels should be positioned to allow all doors to open fully. Panels and doors should be positioned in such a way that they do not impede emergency escape routes.

When positioning printers, space should be allowed for the opening of paper trays and maintenance.

13.2.9 Radio-frequency interference

The manufacturer should be consulted to determine whether the equipment supplied is susceptible to interference. If it is, then the use of portable radio transmitters should not be allowed in the vicinity of sensitive equipment. Any other possible sources of interference should be avoided.

13.2.10 Authorized access

On industrial sites it is likely that new equipment attracts unwelcome attention, particularly when it is located in clean, dry and warm conditions. In order to protect the equipment, a security system should be provided to prevent unauthorized personnel from gaining access. Such a system should be implemented immediately after the equipment is removed from its crates.

13.3 Earthing

NOTE 1 Earthing for instrumentation and control systems is covered in IEC 61918 and IEC 61784-5.

*NOTE 2 For further information on intrinsically safe systems, see Clause **5**.*

Earthing in control rooms and associated rooms should be in accordance with **16.3**.

13.4 Electrical power supplies

NOTE Uninterruptible power systems are covered in BS EN 62040 and batteries for use with telecom, uninterruptible power systems, utility switching, emergency power or similar applications are covered in BS EN 60896.

13.4.1 Quality of supply

A power line disturbance monitor should be connected to the power supply for a period of 1 week to 2 weeks to ensure that the supply meets the minimum requirements laid down in the equipment manufacturer's specification. This test should be carried out immediately after completion of the power supply installation, thus allowing the maximum period of time for any necessary modifications prior to the delivery of the computer/instrumentation equipment.

Before connecting the power supply to any item of equipment, the information on the manufacturer's data plate on the equipment should be examined in order to ensure that the equipment is compatible with the power supply provided.

13.4.2 Standby power supply systems

Standby power supplies such as dual a.c. inverter and battery systems should be tested, where possible, with dummy loads prior to their connection to the computer/instrumentation equipment.

A power line disturbance monitor should be connected to the supply during these tests in order to ensure that the supply remains within the minimum requirements laid down in the equipment manufacturer's specification.

13.4.3 Temporary power supplies

Where it is necessary to provide a temporary power supply prior to completion of the permanent supply, care should be taken to ensure that the temporary supply is secure and meets the system permanent power supply characteristics.

13.4.4 Continuity of supply

Whilst most process control systems are provided with power fail/auto restart facilities, it is not recommended that systems be subjected to continual and repeated power failures, as such treatment can result in the degradation of system performance. Every effort should therefore be made to maintain continuity of supply once power has been applied to a system.

13.5 Protection

13.5.1 Smoke and fire detection

13.5.1.1 Smoke detection

Smoke detection systems, if specified, should be installed and fully tested by the supplier before the computer/instrumentation system is left powered up and unattended.

13.5.1.2 Fire detection

The fire extinguishing system should be installed and fully tested by the supplier before the computer/instrumentation system is left powered up and unattended.

Where gas flooding systems are employed, installation personnel should be made aware of safety procedures associated with such systems.

13.5.2 Surge protection

Where surge protection is specified, the devices should be fitted to the supply lines of the specified equipment only. The rating of surge protection devices should not be exceeded.

At the design stage it should be established whether surge protection is needed for equipment connected to the low-voltage mains and for communications cables for protection against the risks from lightning strikes. SPDs can be used to protect sensitive electronic equipment. They should be connected to the LV supply lines and incoming signal/ data cables.

Surge protection devices for an installation should be selected and applied in accordance with DD CLC/TS 61643-12 for LV systems and DD CLC/TS 61643-22 for telecommunications and signalling networks. At the design for installation stage, it should be established if any instruments to be installed have their own SPDs. If they have then the data on them should be obtained, as these devices have to be taken into account in selecting SPDs for the installation connections.

NOTE General requirements for protection against lightening are given in BS EN 62305-1. PD IEC/TR 62066 also gives general guidance on lightning strikes in relation to complex electrical systems, the effect on LV systems of strikes on MV systems to which they are connected, the interactions between power and communication systems arising from overvoltages and the coordination required in the selection of surge protection devices, taking into account other sources of overvoltage. Risk management for protection against lightning is given in BS EN 62305-2. Requirements for protection against lightning of electrical and electronic systems within structures are given in BS EN 62305-4.

13.5.3 Electrostatic discharges

*COMMENTARY ON **13.5.3***
Electrostatic charging occurs when dissimilar materials are in rubbing or sliding contact (tribocharging) and electrostatic discharge (ESD) occurs when the materials are separated. On separation, the air becomes highly conductive when the voltage is sufficient to ionize it and a spark occurs as the separated charges try to equalize. The size of the charge depends on the conductivity of the two materials, whether the charge between them can leak away and the position of the two materials in the tribo-electric series: the further apart they are in the series the greater the charge. Electrostatic induction can also cause an ESD, when an electrically charged object is placed near a conductive object isolated from ground, which subsequently comes into contact with a conductive path. Discharges can also happen in a vacuum and in any insulating gasses, liquids or solids when their breakdown field strength is exceeded. Common sources of ESD are people, pulleys/conveyor belts, paper and plastic handling, vehicles, furniture, and flowing liquids, vapours, and powders/dusts. ESD can be a significant problem in the process industries where fluids, particles, powders, plastics, paper or rubber are processed. The most common causes of ESD are moving people, low humidity (hot and dry conditions), incorrect or faulty earthing, unshielded cables, poor connections, and moving machines.

Solid-state electrical/electronic equipment is particularly affected by ESD, particularly as miniaturization and packing density increases. DC and low frequency analogue circuits can experience momentary glitches, high frequency analogue circuits can malfunction and this can lead to erroneous data in digital circuits. Components can fail catastrophically or suffer latent damage, leading to reliability problems.

> **WARNING.** Persons whose health depends on the correct operation of body-worn or implanted electro-medical devices should never be near any ESD testing or ESD testing equipment.

The following recommendations should be met for protection against ESD.

a) At the beginning of the installation design, the site requirements for protection against ESD should be established or identified. Instrumentation to be installed should meet these requirements.

   NOTE 1 PD CLC/TR 50404 gives recommendations for hazardous areas, non-conductive solid materials, liquids, gases and powders, and precautions against static electricity on persons.

b) Instrumentation should conform to the relevant product standards for protection against ESD from personnel, when selected for the installed location. See **9.5** and **4.4.4**. Additionally, consideration should be given to the installation of personnel antistatic earthing points on enclosures of sensitive instrumentation.

c) All instrumentation should be earthed. Before installation begins, all earth bonding needed to protect against ESD should be checked. When installing in existing installations, particular care should be taken to inspect the bonding for corrosion and damage, which can be caused by vibration. Faulty bonding should be repaired before the new installation begins.

d) ESD from metal parts can have faster rise times than personnel ESD, due to their low resistance, so can have a higher frequency spectrum than covered by the relevant product standard. Also, discharges can be much greater, due to the higher capacitance of large metal objects. Instrumentation can be at risk from these discharges. Where this risk exists, instrumentation should be assessed against BS EN 60801-2.

e) Installation of instrumentation in an area with a relative humidity of less than 35% should be avoided, due to the increased risk of static build-up. If this is not possible, special precautions should be taken.

f) Installation personnel should wear protective clothing in accordance with site requirements. Nylon clothing is not acceptable. Control room furniture should be ESD-safe. Use of antistatic mats should be considered where there is likely to be a lot of personnel movement.

   NOTE 2 Guidance is given in PD CLC/TR 50404.

g) Moving insulated cables can cause static build-up on the conductors, especially when dragging across artificial fibre carpets or vinyl floors. Before connecting to instrumentation, it should be ensured that all conductors are discharged. If soldering conductors to the instrumentation, soldering irons with an earthed tip should be used.

h) If post-installation testing is considered necessary, it should only be done with the agreement of the site operator and under a permit-to-work system (see **4.3**), as other equipment could be affected. Account should be taken of the risk of causing latent damage, especially where high reliability is required. Testing should be in accordance with BS EN 60801-2.

To control EMC-related functional safety issues, hazard and risk assessments should be carried out and should take into account at least the following issues.

1) What electromagnetic disturbances might the apparatus be exposed to?
2) What are the reasonably foreseeable effects of such disturbances on the apparatus?
3) How might the disturbances emitted by the apparatus under consideration affect other apparatus?
4) What could be the reasonably foreseeable safety implications of the above mentioned disturbances?
5) What level of confidence is required that the above factors have been fully considered and all necessary actions taken to achieve the desired level of safety?

These hazards and risks assessments, and the decisions that arise from them, should be treated as part of the safety validation and should be documented.

All ESD equipment used by personnel on site should conform to BS IEC 61000-4-2.

NOTE 3 Further guidance is given in the IET Guidance document on EMC and functional safety [90].

13.5.4 Lightning

Lightning protection units should be employed where an electronic system is connected to a data transmission line that might be subject to electrical interference, i.e. lightning. The purpose of such units is to protect the system from high voltage transients that can be induced in the data transmission line.

a) Lightning protection units should be installed as close as possible to the equipment being protected, and strictly in accordance with the manufacturer's recommendations.
b) Care should be taken to ensure that the equipment being protected is earthed through the lightning protection unit.

NOTE Where the equipment being protected has its electronic components insulated from its metal case then the metal case may be earthed locally.

c) Input and output cables should always be taken through separate glands and segregated to avoid high voltage transients bypassing the unit.
d) Particular care should be taken to ensure high integrity of the earthing arrangements of lightning protection units. The effectiveness of the unit is heavily dependent on compliance with the manufacturer's earthing recommendations.

13.5.5 Electric arc welding

Some types of interface equipment can be susceptible to damage by excessive induced voltages which can be generated by electric arc welding sets, e.g. as a result of poor earth return paths.

To eliminate the possibility of damage from this source, the interface equipment should be isolated from plant cables while any electric welding operations are in progress.

13.6 Data transmission systems

13.6.1 Signal cables

Signal cables should conform to the recommendations given in **15.3**.

13.6.2 Semi-rigid coaxial cables

Prior to installation, the cable should be checked on its drum with a time domain reflectometer in order to verify that it is undamaged.

The cables should be installed in accordance with the manufacturer's recommendations. Particular attention should be paid to the minimum bending radius permitted and the recommended method of securing to the cable tray, etc. Any distortion in the cable due to a too small bending radius or incorrect clamping could render the cable incapable of high frequency transmission.

The cables should be spliced and terminated by the manufacturer's representative.

Prior to connection to the computer/instrumentation system, the installed cable should be checked with a time domain reflectometer in order to verify that the installation has been completed without damage to the cable.

13.6.3 Fibre optic cables

Fibre optic cables should conform to the recommendations given in **15.6**.

13.7 Field equipment

Field equipment should conform to the recommendations given in **12.5**.

13.8 Testing and commissioning

13.8.1 Special test equipment

The manufacturer should be consulted early in the project in order to establish what, if any, special test equipment will be required to test, commission and maintain the system.

13.8.2 Commissioning spares

An adequate supply of spare parts should be available on site during the commissioning period in order to minimize delays in the event of an equipment failure. Where possible, spare parts should be tested on receipt at site.

13.8.3 System support

Complex electronic systems require a high standard of technical support.

A full set of documentation including software listings should be available to the commissioning team prior to commencement of commissioning.

Valuable time can be saved by having a representative from the manufacturer present during critical commissioning periods.

In order to optimize the performance of the commissioning team, they should complete the manufacturer's recommended training courses on the equipment prior to commencement of commissioning.

A system log book should be established immediately after the system is first powered up. This log should detail every problem encountered together with its solution, every change or modification made and any other comments pertinent to system performance. This form of record can be a useful diagnostic aid, particularly if intermittent system faults are encountered.

13.8.4 Loop checking

Loop checking should be carried out in accordance with **19.8**.

14 Instrument piping and tubing

*COMMENTARY ON CLAUSE **14***
*This clause gives general guidelines for the design, construction and installation of piping and tubing. Recommendations on the storage of equipment prior to piping and tubing are given in **18.3**.*

14.1 General

14.1.1 Classification

Instrument piping and tubing should be classified according to its service as follows:

a) air supply piping (see **14.2**);

b) transmission/signal tubing (see **14.3**);

c) process impulse piping (see **14.4**).

14.1.2 Routing and location

Instrument piping and tubing should be routed such that, where possible, it:

a) is kept as short as possible consistent with good practice and accessibility;

b) does not obstruct traffic through the process plant;

c) does not interfere with the accessibility or removal of process equipment, e.g. pumps, motors and exchanger bundles;

d) avoids hot environments and potential fire-risk areas;

e) will not be subject to mechanical abuse, e.g. used as a step;

f) avoids areas where spillage is likely to occur, e.g. from overflowing tanks;

g) is clear of drainage points of condensate, water and process fluids from adjacent plant equipment;

h) avoids areas where escaping vapours or corrosive gases could present a hazard;

i) avoids process piping and is provided with sufficient clearance from piping that might require lagging.

14.1.3 Installation

Stainless steel pipes and tubes, particularly those containing flammable, toxic or corrosive materials, should not be located where, in the event of fire, there is a chance of molten zinc falling on to the stainless steel from associated galvanized structures, zinc chromate paint, etc., because of the dangers caused by zinc embrittlement of stainless steel.

Pipes or tubes that are installed but not connected should have their ends closed, either by adhesive tape for short durations or caps/plugs for long periods, to prevent the entry of foreign material.

When instrument pipes/tubes are run parallel to each other, joints should be systematically staggered and neatly offset.

Horizontal runs of pipes and tubes should be laid vertically one above the other as far as possible and should be run with the minimum number of changes of direction consistent with good practice and neat appearance.

PTFE tape may be used as a thread sealant for screwed fittings, provided the service operating conditions permit, except in the following circumstances:

- where otherwise specified by the responsible engineer; or
- on instrument air signal lines that are not protected by a filter (see **14.3.1**).

Where modifications are made to existing pipework or tubing systems involving threaded joints, it is essential that traces of previously applied sealant are removed from threads before the connections are remade.

The number of joints in pipework should be kept to a minimum consistent with good practice.

14.2 Air supply piping

Air supply piping (½ in nominal bore and above) between the main air header and the instrument air filters should be galvanized steel or stainless steel with screwed fittings.

Branch headers should be installed that are self-draining and have adequate drainage facilities. On small headers this is normally achieved via the instrument air filter/regulators, but on larger headers, blow-down valves should be provided at low points.

Where the size of instrument air supply piping has not been specified, it should be chosen from Table 1; these sizes are based on a minimum pressure of 4 bar [5] at each take-off point.

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5) 1 bar = 10^5 N/m^2 = 100 kPa.

Table 1 **Air header sizing guide**

Numbers of users	Line size in n.b. [A)]	Metric equivalent mm
1	¼	6
2 to 5	½	15
6 to 20	1	25
21 to 50	1 to 1½	40
51 to 100	2	50
101 to 200	3	80

NOTE A user is an instrument using approximately 0.015 N·m^3/min.

[A)] Nominal bore, in inches.

14.3 Transmission/signal tubing

14.3.1 Pneumatic tubing

*COMMENTARY ON **14.3.1***
Tubing is generally used for the transmission of pneumatic signals which are normally in the range of 0.2 bar to 1.0 bar [6)]. The tubing size normally used is 6 mm outside diameter × 4 mm bore.

Long pneumatic transmission distances should be avoided.

Tubing fittings should be of, or compatible with, the same material as the tubing to which they are connected. Brass fittings are usually used with copper tubing. Care should be taken to ensure that the only fittings used for the installation are those that are required in the design specification.

PTFE tape should not be used as a thread sealant on instrument air lines downstream of filter regulators, including transmission and controller output signals. Where required, a sealing compound should be used, applied sparingly so that no intrusion of the compound into the air lines occurs.

All pneumatic signal tubing should be cleaned by blowing through with filtered air before connection to instruments.

Plastics tubing that is in conduit or closed ducting should preferably not have through couplings. Where these cannot be avoided, they should be made at special junction boxes to be provided for this purpose. The entry to and exit from such conduit or closed ducting, and any joints, should be clean and not have sharp edges or burrs.

Sufficient slack should be provided in all air tubing to avoid strain on the instrument connections and to facilitate dismantling of the instruments. All control valves and direct vessel-mounted transmitters should have an extra loop in their air tubing to allow maximum flexibility.

Where permanent enclosures, trunking or conduits are used to contain tubing, adequate spare space should be allowed internally; preferably not more than 50% to 70% of the cross-sectional area of the enclosure should be occupied by signal lines. A galvanized draw wire of adequate size should be left in the enclosure to enable additional tubes to be pulled in at some future date.

Where condensation is likely to occur in trunking, etc., drain holes at the lowest points should be provided.

[6)] 1 bar = 10^5 N/m^2 = 100 kPa.

14.3.2 Multicore tubing

Where a number of tubes are run together on the same route, a multicore construction, usually comprising 4, 7, 12 or 19 tubes laid-up and sheathed overall with PVC, is generally more suitable than single tubes.

Mechanical protection may be provided by steel wire or tape. Sheathing (or suitable barrier material) should be used where there is a possibility of solvents or acids attacking the plastics tubing; this is especially the case with underground services where hydrocarbon spillage could occur.

NOTE Normally, this is not less than eight times the overall diameter of the multicore.

Multicore tubing should not be bent in a radius less than that recommended by the manufacturer.

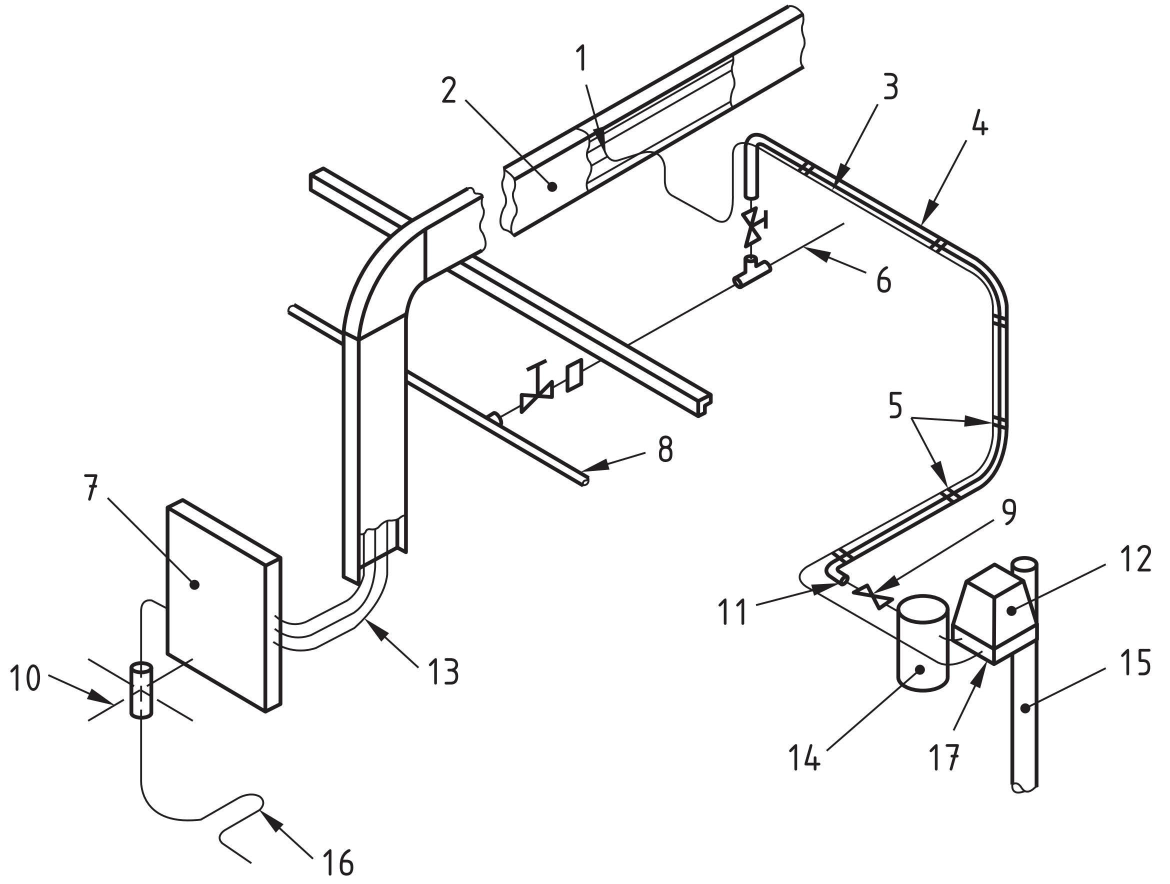
Special care should be taken with multicore tubing having an outer sheathing of PVC when it is being installed at low ambient temperatures. Normally, installation should only take place when the temperature of the multicore cable and the ambient temperature are above 0 °C and have been kept above 0 °C for at least 24 h. Special grades of sheathing are available and should be used for applications where the temperature is likely to remain low for long periods.

Multicore tubing should be terminated in the field using junction boxes similar to those used for electric cables (see Figure 33) but provided internally with bulkhead couplings.

To minimize the length of individually run tubes, the location of junction boxes should be as near as possible to the related instruments.

An allowance of 10% to 25% spare capacity should be provided in each junction box and all spare pneumatic tubing should be connected to the bulkhead couplings.

Figure 33 **Typical field termination of pneumatic multitubes**



Key

1 Compression type couplings
2 Cable trunking or tray
3 Tube to instrument
4 Air supply
5 Soft ties
6 Air supply (close to trunking but clear of sides)
7 Junction box
8 Main air supply
9 Extra valve (if necessary)
10 Ground level
11 Reducer (if necessary)
12 Instrument
13 Tube
14 Air filter and reducer
15 Mounting post
16 Multicore plastic tubes (sufficient slack)
17 Manifold

14.3.3 Tubing materials

Tubing material should be selected to meet the environmental conditions of the plant. Materials in common usage are described as follows.

a) *Copper*. The tubing should be seamless and half-hard annealed in accordance with BS EN 12449.

   Individual copper tubes should be covered with PVC when laid in the open air or in corrosive atmospheres.

b) *Aluminium*. Aluminium has technical disadvantages compared with copper, i.e.:

1) aluminium joints are more difficult to make and virtually impossible to remake;
2) aluminium hardens more quickly under vibration;
3) severe electrolytic corrosion can be expected when aluminium is in contact with other materials;
4) welding spatter can penetrate aluminium.

Aluminium should not be used in Zones 0 or 1 hazardous areas (as defined in BS EN 60079-14) unless coated.

Individual aluminium tubes are usually covered with PVC when laid in the open air or in corrosive atmospheres.

c) *Plastics*. Plastics tubing is usually made from nylon, PVC or polyethylene. It is low in price and easily installed. It does however have mechanical limitations and sometimes it is incompatible with certain working atmospheres. Most plastics materials have a low melting point and consequently they should not be installed in the vicinity of hot process lines or equipment operating at high temperatures. They should also be protected from welding spatter.

   Some plastic pipe will also suffer UV damage over time. Plastics tubing should preferably not be used for critical signals, as it would quickly melt in the event of fire. Plastics tubing that is used for signals, should be installed in accordance with manufacturer's recommendations with respect to the operational environment.

   Particular attention should be paid to limitations of the material with respect mechanical or heat damage. Protection may be offered by physical segregation from sources of damage such as conduit. Plastic pipe work might also require additional support in comparison to metallic tubing systems due to its flexibility.

   During installation and handling, care should be taken to avoid deformation of tubing and to ensure that sufficient slack is allowed on bends to prevent straining or flattening of the tubing.

d) *Stainless steel*. Stainless steel tubing is generally the most durable and corrosion-resistant material. It can withstand arduous service conditions and does not normally need a protective coating.

   The tubing should be seamless and annealed, in accordance with BS EN 10217-7, taking into account the environmental requirements (e.g. offshore/inland).

e) *Alloy*. Alloy tubing is suitable for applications in marine environments such as offshore or coastal sites.

   If cupro-nickel alloy tubing is used, it should conform to BS EN 12449. Cupro-nickel tubing is strong and also ductile; it is easy to handle for installation.

14.4 Process impulse piping

14.4.1 General

*COMMENTARY ON **14.4.1***
The choice of piping (with pipe fittings) versus tubing (with compression fittings) for instrument process hook-ups is dependent upon the service requirements and is a matter of user preference. Generally, tubing is easier to install and is capable of handling the majority of arduous service conditions provided that the tubing and fittings are carefully selected and correctly installed. However, some users believe that piping systems provide greater reliability.

The type of piping to be used should be stated in the piping specification for a particular project.

All impulse piping should be self-draining and in general should be run with a slope of not less than 1 in 12.

The slope of the impulse pipework should be down from the tapping point for liquids, steam and condensibles, and up from the tapping point for gas service, unless special provisions are made for venting and tapping.

Where vents and drains are unavoidable, special attention should be paid to their correct siting to ensure that they are at the highest or lowest points of the piping run, e.g.:

a) vent plugs or valves on high points in liquid-filled lines;
b) drain plugs or valves on low points in gas or vapour-filled lines;
c) filling valves or plugs on high and low points where lines are to be filled with sealing fluids;
d) flushing and neutralizing connections for line and instruments in toxic and/or noxious applications;
e) rodding-out connections on lines that are prone to plugging or coking.

Piping/tubing should be jointed by screwed fittings, socket welded fittings, flanges or compression fittings in accordance with the project specification.

14.4.2 Tubing and compression fittings

The maximum allowable working pressure and temperature for which tubing and fittings are designed should not be exceeded.

Tubing should not be used to carry the weight of pressure gauges, seal pots, etc.; these items should be supported by steel piping, nipples and fittings or suitable brackets.

The tubing material is usually carbon steel or stainless steel, cold drawn, annealed and should conform to BS EN 10216-1 or BS EN 10217-1 as appropriate.

Tubing of outside diameter 10 mm or 12 mm is suitable for most applications. Wall thicknesses should be selected to suit the design working pressure and should have a minimum of 1 mm to give the mechanical strength required.

The body material for compression fittings should be compatible with the process conditions; the compression ring and nut should be compatible with the tubing material.

When installing tubing and fittings, care should be taken to ensure that:

a) the tubing is cut square to the centreline with a suitable pipe cutter, and deburred;
b) the tube end is truly circular and without defect;
c) the compression nut is tightened as prescribed by the fitting manufacturer;
d) suitable tools are used for tube bending.

14.4.3 Piping

Where piping is specified, it should conform to the project piping specification.

Generally ½ in n.b. steel pipe (12 mm) is suitable for most services with socket welded, flanged or screwed connections, depending on the project requirements.

Lined piping, e.g. with PTFE, or plastics pipes might be required for special applications for which no suitable metallic material can be found. These lined pipes are usually factory-made to detailed dimensional drawings of the instrument hook-up.

14.5 Piping and tubing supports

Wherever possible, piping or tubing supports should be kept free from vibrating structures or equipment.

Process piping or handrails should not be used to support instrument piping and tubing.

Piping and tubing runs should be adequately supported and fixed at distances not exceeding those in Table 2.

Cable trays, low carbon (mild) steel or angle bar should be used for continuously supporting copper or plastics tubes and the tubes should be secured at 0.5 m intervals.

Table 2 **Piping and tubing supports**

Size		**Maximum distance between supports or clips**
Metric	**Imperial**	
mm	in	m
Tubing		
10 and less	⅜ in o.d. and less	0.5
12	½ in o.d.	1.0
—	Multicore	1.0
Piping		
10 to 20	⅜ in to ½ in n.b.	1.5
25	1 in n.b.	2.0
40 to 50	1½ in to 2 in n.b.	3.0

When approved for a project, a maximum of three plastics or copper tubes may be supported by clipping the tubes to the air header at 0.5 m intervals.

Capillaries of filled systems should be run independently of all other lines and should be continuously supported using low carbon (mild) steel angle with clips at 0.5 m intervals.

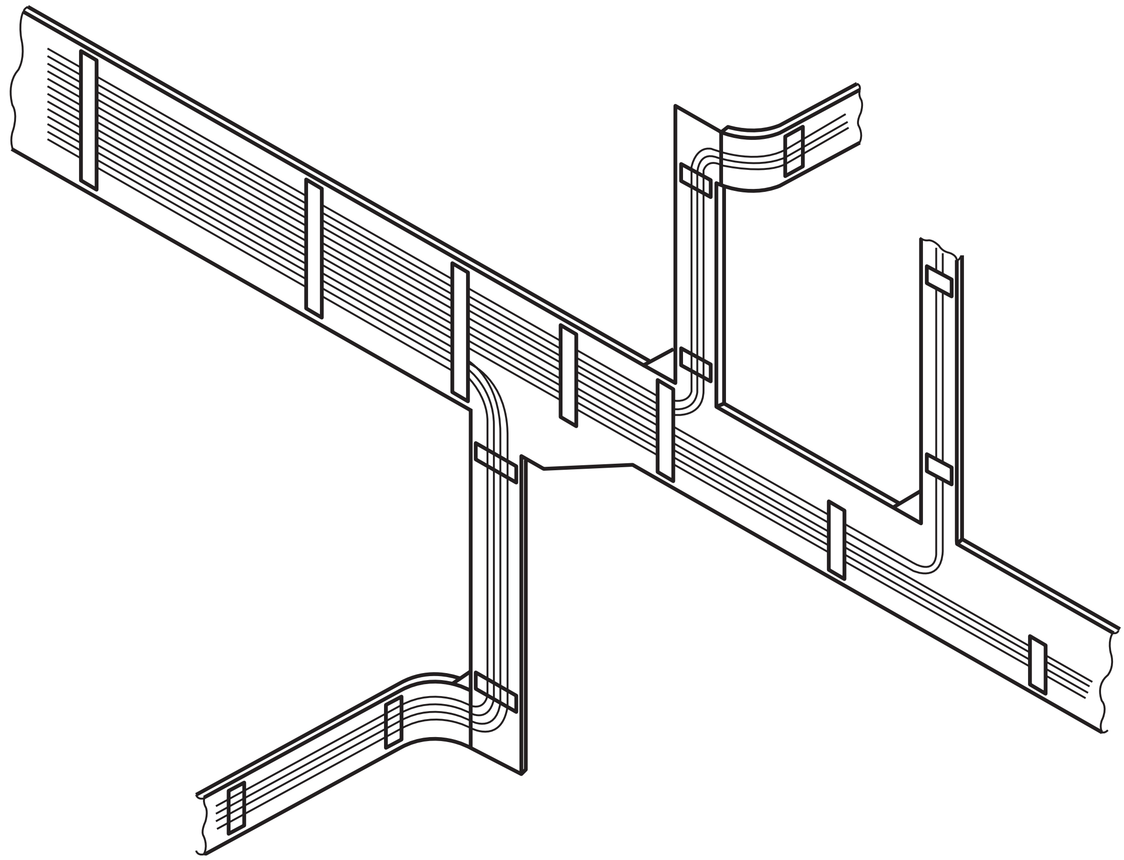
Ladder racks may be used for supporting long runs of multicore tubing.

Cable tray material should preferably be hot-dipped galvanized steel or stainless steel, unless otherwise specified by the responsible engineer, and should be run with the breadth of the tray in a vertical plane. Where a short section needs to be run with the breadth horizontal, the breadth should revert to the vertical plane at the earliest possible point.

NOTE Trunking or conduit may be used to replace cable tray under certain circumstances, such as where additional protection is considered necessary.

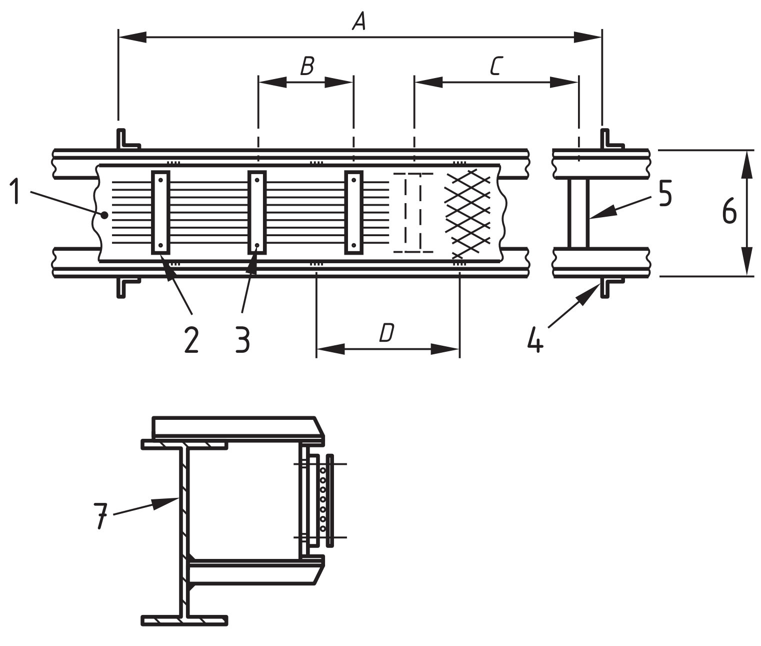
If run in the horizontal plane, the tray should be provided with additional supports to prevent sagging (see Figure 34 for an example of a tray layout).

Figure 34 **Details of copper tubing trays (examples of construction)**



NOTE 1 This example shows trays mounted in the vertical plane.

NOTE 2 The minimum bending radius of the tubing should be taken into account.



Key

1 Galvanized, perforated steel tray (width to suit)

2 Steel strip 25 mm × 6 mm (length to suit)

3 Brass screws 5 mm diameter

4 Steel angle 40 mm × 40 mm × 6 mm

5 Steel strip 40 mm × 6 mm (length to suit)

6 Tray width + 50 mm

7 Plant structure

A Angles supported on structure at 3 m to 4 m centres

B Tubing clipped at 0.5 m centres

C Strips between toes of angles at 1 m centres

D Tray tack-welded to supporting angles at 0.5 m centres

15 Instrument cabling

*COMMENTARY ON CLAUSE **15***
This clause gives basic cabling design and installation recommendations for electronic instrumentation systems. The specific design requirements for a project are normally given in the project documentation. However, the guidance given in this clause is intended for use when other information is not available.

15.1 General

NOTE 1 Attention is drawn to the Construction Products Regulations 1991 [91], the Low Voltage Directive [23] and associated legislation. Attention is also drawn to the following specific legal requirements in respect of cables.

All products supplied for use inside the UK have to meet the requirements of all the appropriate European safety legislation as implemented by national regulations.

The appropriate Certificates of Conformity, ATEX Certificates and Certificates of Incorporation have to be provided for all relevant equipment.

Cable sizes should be calculated in accordance with BS 7671, taking into account all relevant factors including volt-drop. Thermocouple cables should be sized according to BS EN 60584.

Where there is a high density of cables, e.g. in cable tunnels, mezzanine floors and control rooms, low smoke and low toxicity PVC cable sheaths should be used.

The location, layout and routing of cabling should take into account:

- the need to avoid obstruction to cable trunking covers likely to impede cable installation;
- hazardous area cabling requirements (see Clause **5**);
- minimizing the possibility of electromagnetic interference, including signal pick-up or interference with other cables;
- minimizing the risk of accidental damage, in particular from vehicles.

Multicore and multipair cables should penetrate as far as possible into the plant before terminating in junction boxes, to keep subsequent smaller cables as short as possible. Where possible, above-ground runs should be located away from fire hazards.

Fieldbus, ethernet and similar communication systems are increasingly used for transfer of data, among all types of instruments and control rooms, including data for intrinsically safe applications and safety-related applications. Design and installation of these systems should be in accordance with the following standards:

NOTE 2 ISO/IEC 24702 is oriented towards ethernet-based communication.

- ISO/IEC 24702 for all industrial premises;
- IEC 61918 for industrial control systems;
- IEC 61784-5 for fieldbus communications media within and between the Automation Islands;
- BS EN 50174 for generic cabling installation including industrial premises;
- BS EN 50173 for generic cabling design including industrial premises.

15.2 Cable classification

Instrument cables should be chosen according to the situation in which they are intended to be used, using the following classifications.

a) *Classification 1. Instrument power and control wiring (above 50 V)*. This group includes a.c. and d.c. power supplies and control signals, including emergency shut-down control circuits.

Any cable having a total loading of more than 10 A should be regarded as a power cable and be excluded from this classification.

b) *Classification 2. High level signal wiring (5 V to 50 V d.c.)*. This group includes digital signals, alarm signals, shut-down signals and high level analogue signals, e.g. 4 MA to 20 MA.

c) *Classification 3. Low level signal wiring (below 5 V d.c.)*. This group includes temperature signals and low level analogue signals, e.g. analyser measuring circuits.

d) *Classification 4. Communications signals*. This group includes fieldbuses, ethernet and other digital communication systems such as CAN-based systems, and analogue/digital hybrids.

These basic categories can be further subdivided to aid cable/wire identification using tag numbering systems, as illustrated in Table 3.

Table 3 **Cable classification summary**

Description	Classification	Typical designation	Comments
Analogue direct current non-digital signals	2	E	
Thermocouple compensating cable:	3	T	
Type "T" thermocouple compensating cables	3	TT	Copper/copper nickel cores
Type "K" thermocouple compensating cables	3	TK	Copper/copper nickel cores (type "V")
State indication signals (status)	2	A	
Safety-related systems	2	X	
Binary coded digital or frequency signals	2 or 3	D	
24 V d.c. power supply cables	2	J	
110 V a.c. power supply cables	1	H	
230 V a.c. power supply cables	1	H	
Fibre optic cables	—	FO	
Coaxial cables	3	C	
Ethernet cables	4	ET	
Fieldbus cables	4	FB	
Other communication cables not covered above	4	As required	

15.3 Signal cables

15.3.1 Signal segregation

Only conductors carrying signals of the same category should be contained within any one multicore/multipair cable.

In each category, a further segregation should be made to ensure that conductors forming part of intrinsically safe circuits are contained within multicore/multipair cables reserved solely for such circuits.

Signals for the control system should be routed via separate junction boxes and multicore cables to those used by signals for the shut-down system.

High integrity or mission-critical signals should be contained in separate cables, and routed separately from other signals where practicable (see also **15.13**). These signals include data transmission signals from fiscal metering systems or critical shut-down signals.

15.3.2 Signal cable selection (excluding fieldbus cabling)

In general, non-fieldbus instrument cabling should meet the following criteria.

a) Instrument cables installed in general industrial situations should be PVC/SWA/PVC cables with copper conductors conforming to BS 5308-2:1986, Type 2, or should conform to BS EN 50288-7.

b) A risk assessment should be carried out in accordance with BS 8444-3 to establish any need for specialist cables, e.g. low toxicity or fire-resistant cables.

c) Multicore cables should have minimum 0.5 mm^2 copper conductors, insulated in PVC and laid in twisted pairs. The size of conductor will depend on the cable length and volt-drop. Low level field mV, pulse type or data cables should have individual shielded pairs, triads or quads. Other cables should have overall screen only. Multicore cables should have spare cores, which should be terminated at both ends.

d) Thermocouple cables should be sized according to BS EN 60584.

e) Multicore instrument cables carrying digital discrete signals should be multipair with a collective overall screen. Multicore instrument cables carrying analogue signals may be multipair with individually screened twisted pairs plus a collective overall screen.

f) Single pair cables should have minimum 0.5 mm^2 copper stranded conductors, but the design should take account of physical strength requirements. This can include additional mechanical protection (steel wired armour, conduit, etc.). Single pair cables should be insulated in PVC and laid in twisted pairs. Cables for non-IS solenoid valves should be a minimum of 1.5 mm^2.

g) Instrument cables carrying intrinsically safe signals should be marked to indicate that they are part of an intrinsically safe circuit. Where this is achieved by colour, the cable should have a light blue outer sheath and be segregated from all dissimilar cables. All other instrument cables (with the exception of fire and gas) should have a black outer sheath as specified in BS EN 60079-14.

h) Screens of digital and analogue cables should be continuously connected throughout the circuit and be earthed at the one point only. IS circuits should be in accordance with BS EN 60079-25.

i) Cables sizes for cables carrying IS signals should be calculated to ensure that the cables conform to the necessary IS characteristics demanded by the associated equipment certificate.

j) All cables should have an insulation rated at 500 V r.m.s. to earth as a minimum, and should be capable of withstanding an a.c. test voltage of 1 000 V r.m.s. (BS 5308-2:1986, Appendix D).

k) Cables should be suitable for use in ambient temperatures between –40 C and +65 C after installation. Suppliers should be consulted regarding the minimum temperature permitted during the installation of cables (BS 5308-2:1986, Appendix C).

l) Flameproof and general purpose alarm, shut-down and power supply cables should conform to BS 6346 metric laid with a non-hydroscopic filler and PVC extruded bedding.

m) Conductors may be solid or stranded. When stranded conductors are used, crimped connectors should be fitted.

n) Barrier material suitable for the local environment should also be considered when solvents or acids are liable to attack the cabling insulation, especially on buried cables that are prone to attack by hydrocarbon spillage. Where lead sheathing is applied beneath the outer PVC sheath it should not be regarded as a cable screen.

15.4 Temperature signal cables

Temperature signal cables fall into two main categories:

a) thermocouple extension and compensating cables;

b) resistance element cables.

The cable classification guidelines given in **15.2** should be applied equally to temperature signal cables, except that individual screens should normally be used in all multicore and multipair cables.

Mineral insulated metal-sheathed cables, where used, should be installed in accordance with **15.14**.

Stainless steel sheathed cables, where used, should be installed in accordance with the manufacturer's instructions.

15.5 Coaxial cables

Prior to installation, the cable should be checked on its drum with a time domain reflectometer in order to verify that it is undamaged.

The cables should be installed in accordance with the manufacturer's recommendations. Particular attention should be paid to the minimum bending radius permitted and the recommended method of securing to the cable tray, etc. Any distortion in the cable due to a too small bending radius or incorrect clamping could render the cable incapable of high frequency transmission.

Prior to connection to the computer/instrumentation system, the installed cable should be checked with a time domain reflectometer in order to verify that the installation has been completed without damage to the cable.

15.6 Fibre optic cables

Fibre optic cables have the advantage of eliminating problems associated with signal interference and earthing.

Fibre optic cables should be specified and installed in accordance with BS EN 50173-1 and BS EN 50174 and with the manufacturer's instructions, particularly with regard to terminating, jointing and testing.

When designing fibre optic cable systems, the power/attenuation requirements should be considered. Each joint in a fibre optic cable attenuates the signal. The overall attenuation from source to receiver should be calculated so that the power requirements of transmission sources and intermediate amplifiers is known.

When specifying fibre optic cable, consideration should be given to the data-rate, wavelength and bandwidth requirements, and the fibre type to be used.

It is not necessary to segregate fibre optic transmission cables from power cables but they should be installed in a location where they will not be subjected to vibration.

The correct tools and procedures should be used by competent persons for cutting and attaching couplers to the ends of the fibres.

The surfaces on the ends of the fibres should be kept clean and dry.

After installation, the continuity and attenuation of the optical transmission system should be checked.

Fibre optic cable is vulnerable to mechanical damage and hence the cable make-up (armour, etc), handling and installation methods should receive special consideration at the design stage.

When installing fibre optic communication cables, due care should be taken to ensure that the basic cable parameters for bend radii, crushing load and tensile load are not exceeded.

15.7 Fieldbus cabling

The specification, installation and testing of fieldbus cabling should be in accordance with IEC 61784-5 and IEC 61918.

Cabling for fieldbus systems in hazardous areas should conform to BS EN 60079-27.

It is possible to use non-compliant cabling with apparently correct operation of the segment, however the cable should be verified as conforming to the specified standard.

The cable might be less rugged than standard SWA copper core cabling, and care should be taken not to damage the cable by crushing or excessive bending. The manufacturer's cable specifications will provide the installation limitations. If additional mechanical protection is needed, this should be specified by the installation designer.

Fieldbus cables might require individual or overall screens and other mitigation actions to deal with environmental conditions encountered in industrial premises.

15.8 Information technology cabling

Information technology cabling should be designed in accordance with BS EN 50173-1 and BS EN 50174.

15.9 Fire and gas detection equipment cabling

Fire detection equipment cabling should conform to the recommendations given in BS 5839-1.

Gas detection equipment cabling should meet the following criteria.

a) The cables should have a single common coloured sheath (preferably red) that is not used for other cables at the site, and should be segregated from all other cables.

b) Cables carrying intrinsically safe signals should preferably have a red outer sheath with a blue identifier, visible on all cable runs and terminations, and should be segregated from all other cables.

c) Where cables need to be fire-resistant, they should conform to BS 7671 and should be of a pliable construction.

d) The cables should be twisted pairs with overall screen or MICC format.

e) Twisted pair cable conductors should be a minimum 1.5 mm^2 diameter stranded tinned copper and should be suitably sized to take account of volt drop.

f) The cables should be routed and secured to ensure cable integrity and to minimize the risk of cables collapsing into a fire.

15.10 Safety-related system cabling

The location, layout and routing of safety-related cabling should take into account the items listed in **15.1** and the following:

- safety integrity level of the safety function;
- segregation of safety system cabling from other cables and from other safety integrity level loops (see **15.3.1**).

Where safety-related information is communicated using fieldbus technology, the recommendations given in **15.7** should be followed, together with any specific manufacturer's instructions.

NOTE Bus-based safety communications may be designed to share the same physical cable as non-safety communications, with segregation being provided by software security.

15.11 Mineral insulated copper cables (MICC)

MICC cables may be used where there are specific requirements for such a cable type. Care should be taken to ensure that the correct physical protection is provided and that the correct installation techniques are implemented. See **15.14**.

15.12 Cable routing

The main routing of instrument signal cables, whether above or below ground, should take account of safety, convenience and other factors. In all cases, the shortest practical routes should be selected.

Site-run cabling should be routed bearing in mind the following considerations, such that, where possible, they:

a) are kept as short as possible consistent with good practice and accessibility;

b) do not obstruct traffic through the process plant;

c) do not interfere with the accessibility or removal of process equipment, e.g. pumps, motors and exchanger bundles;

d) avoid hot environments and potential fire-risk areas;

e) will not be subject to mechanical abuse, e.g. used as a step;

f) avoid areas where spillage is liable to occur, e.g. from overflowing tanks;

g) are clear of drainage points of condensate;

h) avoid areas where escaping vapour or corrosive gases could present a hazard;

i) avoid process piping and are provided with sufficient clearance from piping that might require lagging.

In areas where the foregoing hazards cannot be totally avoided, consideration should be given to installing the cables within metal conduits or trunking. Heat insulation and fire-retarding materials may be applied externally to the trunking in order to give additional protection in high fire risk areas.

Where possible, above ground cable routes should be selected to maximize the physical protection afforded by structural steelwork.

The layout of cable trays where possible should be such that only the instruments in the immediate vicinity will be affected if a local plant fire damages the signal lines.

Where signal lines pass through hazardous areas of different classification, e.g. through walls of pump rooms or control rooms, the transition points should be pressure-tight.

Where circuits traverse a hazardous area in passing from one non-hazardous area to another, the wiring system in the hazardous area should be appropriate to the zone(s) (as stated in BS EN 60079-14:2003, **9.1.7**). The cable is not a certified piece of equipment and hence there are no specific requirements regarding the installation. However, any equipment installed in a hazardous area should be suitable for that area (see **5.2**).

Segregation between cables and signal types should meet the recommendations given in **15.3**.

15.13 Cable separation

15.13.1 General

Cable separation should be considered on a project basis in order to minimize interference due to pick-up or noise from other cabling. Much depends upon the type of cabling used and the noise rejection capability of the apparatus to which the signal cables are connected. In the absence of specific project requirements, the recommendations given in **15.13.2** and **15.13.3** should be followed for good installation practice.

Digital and analogue signals should not be in the same cable.

15.13.2 Separation from power cables

Instrument cables should be routed above or below ground separately from electrical power cables (i.e. a.c. cables usually above 50 V a.c. with a 10 A rating).

Parallel runs of instrument cables and power cables should be avoided; however, where unavoidable, adequate physical separation should be provided. A spacing of 250 mm is recommended from a.c. power cables up to 10 A rating. For higher ratings the spacing should be progressively increased.

Where a cross-over between signal and power cables is unavoidable, the cables should be arranged to cross at right angles with separation of at least 250 mm maintained by positive means.

15.13.3 Separation between instrument cables

Instrument cables should be separated into four groups according to the signal classification (categories 1, 2, 3 or 4, see **15.2**). Examples of separation figures are given in Table 4.

Table 4 **Example of cable separation**

Classification category	Spacing mm
1 to 2	200
2 to 3	300
1 to 3	300
1 to 4	300
2 to 4	300
3 to 4	300

Within category 2, analogue signal cables should be laid on the side remote from category 1 cables, i.e. so that analogue signals are furthest from instrument power and control signals. Cable separation should be maintained both for above and below ground installations. The problem of electrical interference becomes more acute where long parallel runs are unavoidable.

Whenever possible, the cables of emergency shut-down circuits should take an independent route from the cables of other systems which they protect, in order to afford higher integrity.

Intrinsically safe circuits should be contained in separate cables and terminated separately, otherwise segregation should be the same as for other signal cables in the same group.

15.14 Instrument cable installation

The following recommendations should be met for the installation of instrument cables.

a) During installation, multicore and multipair cables should not be bent in a radius less than the manufacturer's recommended minimum bending radius (normally not less than eight times the overall diameter).

b) To avoid risk of damage to the PVC outer sheathing during installation at low temperatures, cables should be installed only when both the cable and the ambient temperatures are above 0 °C and have been for the previous 24 h.

NOTE 1 Special grades of sheathing are available for use in sustained low-temperature applications.

c) Where cables are run through pipes or conduits, the entries and exits should be smooth and free from burrs. Care should be taken when cables are pulled into such conduits to ensure that there is no damage to the cable.

d) For metallic conduit, all conduit runs should be mechanically and electrically continuous. However, conduit should not be used as an earth continuity path. Running threads should be secured by locknuts. After conduit is installed, all exposed threads should be painted with a sealing compound.

e) Where conduits terminate at cabinets, terminal boxes or trunking, they should be securely locknutted, bushed and ferruled. Sharp edges should be removed and conduits not otherwise connected should be terminated in smooth bushes.

f) Conduit or mineral insulated metal-sheathed cables should be neatly run, attached to supports, structures and steelwork.

g) Care should be taken when PVC conduit or ducting is used, to ensure that it is not run adjacent to plant or equipment operating at temperatures that would subject the conduit/ducting to temperatures outside its specified range.

h) Conduit junction boxes should be provided at distances not exceeding 9 m with not more than two right-angle bends occurring in one pull.

i) When flexible conduits are necessary, they should be in accordance with BS EN 61386-1.

j) Where mineral insulated copper cables (MICC) are used, it is essential that all seals be made using the correct components and the methods specified by the manufacturer, and that correct insulation resistance tests are carried out.

k) Where mineral insulated copper cables are not immediately glanded, they should be temporarily sealed after cutting.

l) Immediately after cables are laid and before connection, all thermocouples, electrical and electronic instrument wiring should be checked for polarity, continuity and insulation resistance between conductors and between conductors to earth. These tests should be carried out before final loop power-off tests.

m) The cables should be run above ground on cable tray or ladder, or below ground in ducts or by direct burial. Field cables should be steel wire armoured.

n) All cables should be securely glanded at each end. Glands should be suitable for the environment in which they are located. Glands installed within hazardous areas should be certified for the hazardous area classification, the required IP rating, and the equipment that they terminate into. All cable glands should conform to BS EN 50262 and be suitable for their duty. Armoured cables should be glanded using double seal brass compression glands with integral earth or brass earth tags. Glands used outdoors or in damp situations should be protected to IP66.
To permit the free and easy inspection of glands, gland covers/shrouds should not be used.

o) Cabling connected to instrumentation having elements containing flammable gas should be provided with an epoxy-filled barrier type flameproof gland at the instrument connection where alternative systems are not available.

p) All power, electrical, control and instrument cables should be installed in continuous lengths. Cable joints should not be used.

q) All instrument cables should be terminated as detailed in **15.15**. Power cables should be terminated using correctly sized compression lugs where necessary.

r) Protection and control system communications cables (including industrial ethernet, safety bus and serial communications) may be non-armoured but should be run in continuous conduit for protection.

NOTE 1 Requirements for SMART, CAN and generic fieldbus cable installations are specified in IEC 61918.

s) Ethernet based fieldbus should be in accordance with ISO/IEC 24702.

t) For installation purposes, a specific fieldbus application may be further sub-divided into categories such as:

- technology: optical cable, copper cable, wireless;
- connection: single pair, 2 pairs, 4 pairs;
- topology: linear bus, tree, ring.

NOTE 3 A ring-based fieldbus may be installed using a star or hub-and-spoke layout to provide a common location (start point or hub) for diagnostics and ease of addition and removal of devices in the ring.

u) An installation should use appropriate protection and mitigation techniques to maintain integrity of the installed cable and the signals it transmits. MICE classification categories are recommended as a basis for identification of environmental influences that might be present for the whole or specific parts of a cable when installed in an industrial application. MICE refers to categories of mechanical, ingress, climatic, and electromagnetic stress as specified in ISO/IEC 24702.

*NOTE 4 Additional installation constraints are applicable for communication installations used for safety applications and hazardous applications; see Clause **4**.*

15.15 Junctions and terminations

*NOTE See Clause **16** for details of earthing recommendations for junction boxes and similar installations.*

The following recommendations should be met for junctions and terminations.

a) Cable joints should be made only at appropriate terminals in instruments, junction boxes or approved equipment. No intermediate joints should be made on cable trays, ladder racking or in conduit.

b) Junction boxes should be installed in accessible locations, be fitted with fixed terminals suitably rated and identified, and have an IP rating (as specified in BS EN 60529) and an IK rating (as specified in BS EN 62262) applicable to the location and environment.

c) Junction boxes should ensure sufficient space for termination requirements. Cable entries should be through the base and sides only. Cable glands should be used to anchor the cable and provide a seal.

d) All junction boxes should be provided with a minimum of 20% spare terminal and cable entry capacity.

e) All junction boxes should be clearly identified and uniquely labelled.

f) Junction boxes should be selected to give the degree of protection appropriate to the hazardous area within which they are installed and should be suitably certified where required.

g) Junction boxes should be fitted with sectional type, screw clamp terminals mounted on rails. Sufficient terminals should be provided to terminate all signal wires (including spare wires) and for connecting the cable screens where appropriate.

h) Where specified in the original design, cable glands should be insulated from the junction box to permit the earthing of the cable sheath and/or armour at one point only (see **16.4**). In cable terminations where armour/sheath and screen are not earthed, they should be positively isolated from each other.

i) All terminations should be made with approved tools. Crimped type terminations should be used for stranded conductors. Where instruments are fitted with flat-headed screw-type terminals, wire ends should be fitted with crimped spades having a retaining lip.

j) Sufficient slack wire should be left neatly looped at terminals to permit remaking terminations, alterations and testing.

k) Where a termination is made to a measuring element that has to be withdrawn, e.g. a thermocouple, sufficient length of flexible cable should be allowed, if possible, for the element to be withdrawn without electrical disconnection.

l) Coaxial and other special cables should be terminated in accordance with the manufacturer's instructions.

m) Where cables are terminated, cable clamps, glands or similar should be used to anchor the cables.

n) Cables and terminals should be ferruled and identified in accordance with the project requirements. Identification should be clear, and wires should carry ferrules bearing the same number as the terminal identification so that there is no confusion as to which terminal a wire belongs.

o) Signals from field-located instruments may be marshalled in junction boxes located in the field and run in multicore cables from these junction boxes to the control room. Each transmitter or field device should be connected to its designated junction box by a cable having only sufficient cores to allow its proper connection.

p) Cable ends should be terminated via crimped, pre-insulated cable connectors and individually identified.

q) Signal segregation within the cables should not be compromised within the junction box.

r) Multi-category junction boxes may be installed in safe area locations with suitable physical segregation.

s) The layout should be so arranged to give a neat and professional appearance in the location of the junction box.

t) Connections should conform to the relevant requirements in BS 7671.

u) No core should be left unidentified or un-terminated.

v) Unused cores should be earthed at each end of the cable.

15.16 Cable tray and supports

The following recommendations should be met for cable trays and supports.

a) Cable trays should preferably be run with the breadth of the tray in a vertical plane. Where a section has to be run with the breadth horizontal, the breadth should revert to the vertical plane at the earliest possible point. If run in the horizontal plane, the tray should be provided with adequate supports to prevent sagging (see Figure 34 for an example of a cable tray installation).

b) Clips, saddles and strapping securing cables to steelwork or trays should be metal, preferably with a plastics coating. The spacing of cable clips should be not more than 250 mm on vertically run or 500 mm on horizontally run cable trays.

c) Cable ties should be suitable for the life of the plant.

d) Cables in enclosures should be neatly bundled and tied. Cables with an overall diameter above 40 mm should be individually secured when installed on cable ladder/tray which rises vertically for more than 3 m.

e) Cables should be secured in accordance with the cable manufacturer's recommendations, the installation environment, and to survive a plant fire situation, e.g. the suitability of PVC cable ties or all-round band should be established.

f) Where signal cables are run in trunking, spare space should be left in accordance with the design requirements. Preferably, not more than 50% to 70% of the cross-sectional area of the trunking should be occupied by the cables.

g) Where condensation is likely to occur in trunking, etc., drain holes should be provided at the lowest points.

h) All cables should be continuously supported using a proprietary cable installation system. Where metal tray is used, this should be bonded to earth.

i) Armoured cables within buildings and on plant structures should be installed on cable ladder or cable tray. Cables should be double layer maximum for control cables and single layer for power cables.

j) Cable manufacturers' recommendations regarding installation, support spacing and minimum bending radius should be strictly adhered to.

k) All cable containment systems should be adequately sized and routed to all appropriate locations.

l) All tray work should be installed generally on a horizontal or vertical plane. All direction changes should be done with proprietary bends.

m) The bending radius for the cable tray bends should be not less than ten times the largest overall cable diameter to avoid any undue strains on the cables. In situations where proprietary bends do not meet this recommendation, the slow bend should be formed using appropriate templates.

n) Where it is not possible to use proprietary bends, any cutting of tray work or such modifications, which results in damage to the galvanized protective covering, should be painted with a suitable paint as specified by the tray manufacturer.

o) Cable ladder and cable tray should generally be heavy duty galvanized steel conforming to BS EN ISO 1461, suitably rated for the load-bearing duty, and should be sized to accommodate the required number of cables plus 20% spare capacity.

p) Cable tray should be fitted with tray covers when installed within areas where heavy deposits of dust/dirt can collect, where cables are directly exposed to the atmosphere, where the tray is required to be cleaned down regularly or where exposed to rodent attack.

q) The cable rack and tray should maintain head clearance levels set in the neighbourhood and should not intrude on access points, road or walkway.

r) The cable support system should be attached to the mounting bracket steel work by galvanized bolts.

s) The cable support system should be erected in such a manner that the necessary segregation and separation of cables is maintained.

15.17 Cable trenches

Cable trenches should preferably be excavated in open ground, avoiding paved areas and obstructions, both above and below ground, so that reasonable access to the buried cables can be achieved. A minimum clearance of 300 mm should be maintained between cables and parallel runs of underground piping.

Underground cables should be tested before trench backfilling is commenced. Cables should be buried to a depth of 750 mm (measured from the top surface of the top layer of cables) for uncovered backfilled trenches and to a depth of 450 mm for concrete-covered sand-filled trenches. The cables should be bedded in a layer of soft sand or other suitable cushioning material, extending 75 mm minimum below and above the cables. This layer should be protected by earthenware or concrete cable covers, a marker tape laid above the cable, and the trench backfilled and compacted until the ground is restored to its original grade and finish.

Underground cable routes should be identified by concrete cable markers positioned at 30 m intervals on straight runs and at points where the route changes direction. Where trenches are wider than 1 m, markers should be located on both sides of the trench.

Cables should preferably be laid in single tiers but, owing to space restrictions, it might be desirable to use multiple tiers, in which case due consideration should be given to heat dissipation and cable segregation (see **15.3**).

Where cables leave trenches, a risk assessment should be undertaken concerning potential damage from machinery and personnel, and appropriate measures should be taken to protect the cables.

If there is likely to be heavy underground chemical attack, underground cables should either have a suitable protective sheath under the outer PVC sheath (see **15.3.2**) or be laid in a concrete, crack-free, watertight or acid-resistant trench filled with sand. Because of the cost involved in the latter arrangement, such trenches should be limited to the distance from the control room to the nearest riser point. Under such adverse conditions it is advisable to install the cables above ground where possible.

All underground trench/duct systems carrying external cables should be adequately sealed against weather and rodent attack.

Where wiring/cabling systems pass through walls and floors, the openings remaining after passage of the wiring/cabling system should be sealed according to the degree of required fire resistance. Cable trunking and conduit should also be sealed to maintain the required fire resistance. Where necessary this should include barriers against the passage of hazardous gases or liquids (cable transits). Proprietary wiring/cable barriers or transits should be used where possible.

15.18 Cable marking

All cabling should meet the following marking criteria.

a) All cables should be identified at each end and at relevant intermediate points (e.g. Drawpit) using a proprietary cable marker. Cables should also be marked on each side of a penetration.

b) Each cable core including spare cores should be identified at each end using approved markers. The identification code should comprise a letter or letters to denote the cable's function followed by numbers identifying the individual core.

15.19 Panel wiring

15.19.1 Wiring colours

BS 7671 and BS EN 60204-1 give differing colour schedules for cabling and wiring. BS 7671 applies principally to voltages above 24 V and is not considered to apply to instrument and control cabling and wiring. Hence it is recommended that the following colours are used for instrumentation and controls:

- AC power:
  - line: brown;
  - neutral: blue;
  - earth: green-and-yellow;
- DC power:
  - negative earth +24 V d.c.: red;
  - negative earth –24 V d.c.: dark blue;
  - positive earth –24 V d.c.: grey;
  - positive earth +24 V d.c.: dark blue;
  - analogue signals: pink;
  - digital signals: pink;
  - logic: orange.

IS cables and wiring between terminals and barriers should be segregated and light blue.

For specific purposes the following additional colours may be used (BS EN 60204-1): yellow, violet, white, turquoise. Alternatively colour stripes may be added to indicate particular requirements. However, green or green-and-yellow should not be used, to avoid confusion with circuit earth protective conductors.

15.19.2 Panel terminations

Cable entry should be by a gland plate or similar. The gland plate should be bonded in accordance with BS 7671 to the panel earth bolt.

Panel terminals should be provided for the secure termination of field cables and the transition to panel wiring.

All terminals should have clamp type terminals and be suitable for rail mounting.

Terminals, isolators and intrinsic safety barrier rails should be installed with a minimum of 20% unused rails to allow for future expansion.

Terminals should be selected with swing link disconnectors and socket screws or equivalent to allow for non-invasive testing.

Main power supply isolation should be provided by double pole fused isolator/disconnector. Isolation should be sized to minimize voltage drop and should allow the termination of heavy input supply cables (minimum 10 mm^2).

Equipment protection should be by fuses or double pole banked miniature circuit breakers,.

All 110/230 V a.c. terminals should be provided with covers giving minimum ingress protection of IP21 and should be suitably labelled.

15.19.3 Installation

All wiring should be run in plastic tray/trunking and strapped as required.

Wiring for power and other instrument signals should be run in separate trunking. Intrinsically safe circuits should be segregated from non-intrinsically safe circuits. Separation should be 50 mm in air or by physical (barrier) separation (BS 60079-14:2003, **12.2.3**).

The internal control and d.c. wiring should be to a minimum of 0.5 mm^2 and should conform to the appropriate part of BS 5308. Low smoke, low toxicity cables should be used.

The internal a.c. circuits should be to a minimum of 1.5 mm^2 and should conform to the appropriate part of BS 5308. Low smoke, low toxicity cables should be used.

All cable cores and wires including spares should be numbered at each end using approved markers.

16 Earthing

*COMMENTARY ON CLAUSE **16***
Correct system earthing is critical to the safe and reliable operation of all instrumentation systems. In practice the earthing criteria for the instrumentation systems within a particular installation are dictated by the electrical power system design. These criteria are documented within electrical power standards such as BS 7430 and BS 7671.

16.1 General

Earthing and bonding should be generally in accordance with BS 7430 and BS 7671 unless otherwise specified.

Surge protection should be in accordance with **13.5.2**. Electrostatic discharge protection should be in accordance with **13.5.3**.

All instrumentation equipment, including enclosures, cable armouring and screening, should be securely bonded so as to form an effective equipotential plain, provide the maximum possible rejection of electrical interference and help to ensure personnel safety.

Manufacturers of instrumentation systems should specify the earthing requirements for their particular equipment in detail and provide these details to the designer and installer as required.

The size of cable used should meet the minimum requirements of the design specification. The use of smaller or incorrect cables could significantly degrade the performance and safety of the earthing system.

16.2 Design considerations

Care should be taken when designing and installing instrument earthing systems to avoid the creation of earth loops by permitting earth conductors to contact earthed steelwork or by duplicating earth conductors. This is generally achieved by adopting a single point earthing system where each subsystem can be referenced to one point, held nominally discrete from other subsystems except for connection at the single reference earth point.

The cross-sectional areas of earthing and bonding conductors should conform to BS 7430. The following summary guidance values should be adhered to for separate earthing or bonding conductors (i.e. one not contained in a composite cable); cross-sectional area should not be less than the following, not withstanding any thermal constraints as identified within BS 7430:

a) 2.5 mm^2 where mechanical protection and protection against corrosion is provided;

b) 4 mm^2 where protection against corrosion only is provided;

c) 16 mm^2 where buried in the ground and protection against corrosion only is provided;

d) 25 mm^2 where buried in the ground and corrosion protection is not provided.

16.3 Control room and associated rooms

NOTE 1 Earthing for digital communications for measurement and control systems is covered in IEC 61918 and IEC 61784-5.

*NOTE 2 For further information on intrinsically safe systems, see Clause **5**.*

Correct system earthing is critical to the safe and reliable operation of instrumentation systems, particularly for computer installations and in distributed control systems and programmable logic controllers. Before installation, it should be confirmed that all the necessary instructions for earthing are available.

The size of cable used should be in accordance with the design specification. The use of smaller or incorrect cables could significantly degrade the performance and safety of the earthing system.

Earth connections from each individual unit should be connected directly to the system earth. It is not recommended to connect to the system earth by loop connections between units.

Computer/instrumentation earth cable should be clearly identified at its termination points and at regular intervals along its length.

16.4 Control centre earthing

In principle the control centre instrumentation earthing arrangement should form a single earthing system, connected to the main earth electrode system at one point only, with the following exceptions.

a) Where there is a mixture of intrinsically safe and non-intrinsically safe systems, a separate earthing system should be provided for each, with individual connections to the main earth electrode system.

b) Where there is earthing for the purpose of static dissipation, this should be connected to the main power earth.

The control centre earth connection facility should be designed to carry the calculated earth fault current. Historically this has consisted of a bare copper busbar with a minimum cross-sectional area of 75 mm^2, mounted on insulators and spaced at least 25 mm from earthed conducting surfaces; however, alternative arrangements are now commonplace. The installer should always refer to the specific plant design, for the minimum cross-sectional area which should be calculated in accordance with BS 7454.

The control centre earth connection facility should be connected to the main plant earth electrode system by two identical copper conductors. These conductors should be insulated and protected from mechanical damage.

Each control panel or termination cabinet should be provided with an earth reference plane(s) (previously known as earth reference bars), the physical nature of which should use the same design philosophy as the control centre earth connection facility. Particular attention should be paid to the isolation of earth reference plane in panels, control rooms and outstations.

The earth reference plane should be connected to the control centre earth connection facility by an appropriately sized, insulated copper conductor. The appropriate size should be determined by calculating the minimum conductor diameters in accordance with BS EN 60205.

A requirement for a maximum earth loop impedance between the earth reference plane and the main site connection to true earth potential should be specified as part of the installation power earthing design. The instrumentation earthing system should meet this requirement or the lowest of the following:

1) the earth loop impedance requirements of the certification for intrinsically safe circuits;

2) electrical safety requirements;

3) other special system requirements.

Before testing the insulation resistance, a detailed assessment should be undertaken to ensure that delicate electronic equipment will not be damaged by application of the test voltages.

With the conductors between the control centre earth connection facility and the main plant earth temporarily disconnected, the insulation resistance between the control centre earth connection facility and the main plant earth system should be not less than 0.5 MΩ, measured at 500 V d.c. and applied for at least 1 min. If the control centre supply voltage exceeds 500 V, the insulation resistance should be in accordance with BS 7671.

16.5 Cable earthing

All cable screens should be earthed.

Continuity of the screen should be maintained throughout cable runs, and screens should be isolated from earth at all other points.

Intrinsically safe and non-intrinsically safe circuits should have separate earthing systems connected to the control centre earth or main plant earth.

Cable armour should not be used directly as a means of screening cables. It should be used to provide physical protection only. The armour should be earthed or insulated from earth at junction boxes, field equipment and control room.

16.6 Field-mounted instrument enclosures

Where equipment with a voltage of not more than 50 V a.c. or 110 V d.c. is located within a metal enclosure and this is in turn supported from an earthed plant structure, the equipment is deemed to be earthed via metal-to-metal contact through the supports.

Equipment with higher voltages, or not supported from the earthed plant structure by metal-to-metal contact, should be connected to the nearest plant earth bar by means of a suitably sized green-and-yellow PVC insulated copper wire.

All metal field junction boxes should be positively earthed to the nearest plant earth bar using suitably sized green-and-yellow PVC insulated copper wire.

16.7 Instrument cable racks, trays and conduit

Cable racks, trunking trays and conduit should be provided with gaps or suitable insulating spacers to prevent the circulation of induced currents as required. Each section should be electrically earthed. Fixings to non-metallic structures, e.g. brickwork, should not be regarded as earth connections.

16.8 Installation guidance

Earth connections from individual units should be made directly to the system earth. Connections should not be made to the system earth by loop connections between units.

During the installation, care should be taken to ensure that all parts of the system, including cables and joints, are adequately protected against the possibility of damage or corrosion.

Where the system design specifies a separate and dedicated earthing arrangement, care should be taken to ensure that no items of equipment other than those specified are connected to that dedicated earth.

Where the system design specifies a single connection from an individual item of equipment, e.g. computer/instrumentation equipment, to the main plant earth, care should be taken to ensure that no additional items are connected via this single connection to the main plant earth.

General practice in such systems is to provide a removable test link within the connection between the equipment earth and the main plant earth. During the earthing system installation, regular tests should be carried out to ensure that with this link removed, the two earthing systems remain isolated. On completion of the installation, a final test should be carried out again to ensure that the two systems remain isolated. This removable link should be clearly labelled with a warning indicating that it should only be removed following disconnection of all electrical supplies to the associated equipment.

All cables associated with the installation of the earthing system should be clearly identified at their termination points and at regular intervals along their length.

Where equipment enclosures are earthed via the equipment earth connection, care should be taken to ensure that the enclosures are insulated from structural steelwork or any other adjacent structure connected to the plant earth system. In such cases, care should be taken to ensure that the enclosure design does not contravene BS 7671 with regard to the relative earthing of adjacent equipment housings.

16.9 Conformity to design

Where the design specifies a separate and dedicated earthing arrangement, a maximum earth electrode resistance should be stated in the design. Once the system is installed, a check should be carried out in accordance with BS 7671 in order to confirm that this figure has not been exceeded.

17 Electrical power supply systems

NOTE This clause covers the basic recommendations for power supplies to instrumentation systems. For safety of personnel working on electrical power supply systems, see ***4.14****.*

17.1 General

The electrical installation should be in accordance with BS 7671. However, the following details are given as a guide to be followed in the absence of other information.

WARNING. Particular care needs to be taken to ensure correct connection of phases and neutral, and all conductors should be treated as live. This is important when installing in existing installations, because the colour coding specified in BS 7671 for phase and neutral conductors in new installations changed in 2004. Table 5 lists both pre- and post-2004 conductor insulation colours for fixed installations. These do not necessarily apply to conductors within equipment and instruments. It is strongly recommended not to rely on conductor insulation colours alone to identify live and neutral conductors, either in the installation or the equipment.

Table 5 **Identification of conductors in fixed installations**

Function	Alpha-numeric	Colour	Colour coding applicable prior to April 2004
Protective conductor		Green-and-yellow	Green-and-yellow
Functional earthing conductor		Cream	
a.c. circuit [A)]			
Phase of single-phase circuit	L	Brown	Red (or yellow or blue)
Neutral of single-three phase circuit	N	Blue	Black
Phase 1 of three-phase circuit	L1	Brown	Red
Phase 2 of three-phase circuit	L2	Black	Yellow
Phase 3 of three-phase circuit	L3	Grey	Blue
Two-wire unearthed d.c. power circuits			
Positive of two-wire circuit	L+	Brown	Red
Negative of two-wire circuit	L–	Grey	Black
Two-wire earthed d.c circuits			
Positive (of negative earthed) circuit	L+	Brown	
Negative (of negative earthed) circuit [B)]	M	Blue	
Positive (of positive earthed) circuit [B)]	M	Blue	
Negative (of positive earthed) circuit	L–	Grey	
Three-wire d.c. circuits			
Outer positive of two-wire circuit derived from three-wire system	L+	Brown	Red
Outer negative of two-wire circuit derived from three-wire system	L–	Brown	Red
Positive of three-wire circuit	L+	Brown	Red
Mid-wire of three-wire circuit [B), C)]	M	Blue	Black
Negative of three-wire circuit	L–	Grey	Blue
Control circuits, ELV and other applications			
Phase conductor	L	Brown, Black, Red, Orange, Yellow, Violet, Grey, White, Pink, Turquoise	
Neutral or mid-wire [D)]	N or M	Blue	

A) Power circuits include lighting circuits.

B) M identifies either the middle wire of a three-wire d.c. circuit, or the earthed conductor of a two-wire earthed d.c. circuit.

C) Only the middle wire of three-wire circuits may be earthed.

D) An earthed PELV conductor is blue.

NOTE 1 Maintenance logs supplied with machinery are required by legislation to be kept up to date. Tools and equipment, including IT equipment, that are plugged into the mains are required to be inspected before being put into use in the workplace and at regular intervals thereafter. They are to be maintained in a safe condition.

NOTE 2 Guidance is given in the IET Code of practice for in-service inspection and testing of electrical equipment [92].

Inspection and maintenance logs should be provided and kept up to date for all electrical tools and equipment that plugs into the mains.

The use of extension leads should be avoided wherever possible. When extension leads are used they should be restricted in length according to their core size, in accordance with Table 6.

Table 6 **Maximum cable lengths for extension leads**

Core area	Maximum length
1.25 mm^2	12 m
1.5 mm^2	15 m
2.5 mm^2	25 m

NOTE 3 Leads longer than these are covered under BS 7671 and are required to be protected by a 30 MA RCD to conforming to BS 7071.

The 2.5 mm^2 cable should be fitted with an industrial connector conforming to BS EN 60309; shorter cables should use a standard plug conforming to BS 1363-1.

Extension leads should always be fully unwound unless protected by an over-current protective device. Precautions should be taken to prevent trips and falls over extension leads.

17.2 Power supply categories

The design considerations for electrical power supplies to instrumentation and control systems should be for the safe and continuous operation of the process plant. On plants where loss of electrical supply to instrumentation and control systems can cause hazards or serious loss of production, it is normal practice to have several separate power supply systems that are each designed to give the required level of availability.

These power supplies fall into the following categories according to the significance of the apparatus which they supply for the safe operation of the plant:

a) electrical power supplies that are continuous (uninterruptible power supplies or UPS, e.g. standby generators, floating battery systems and independent secondary supplies);

b) electrical power supplies whose output can be subject to interruption for a short time;

c) electrical power supplies where longer duration interruption can be tolerated.

It is essential that each instrument and control circuit is connected to a power supply system providing the correct level of integrity.

Examples of equipment connected to each power supply type are:

1) emergency shut-down systems should be connected to type a);

2) alarm systems should be connected to type b);

3) non-critical analysers should be connected to type c).

BS 7671 specifies requirements for electrical services for safety applications.

17.3 Design considerations

Power supply systems should be suitable for the connected apparatus in all respects, i.e. voltage level, voltage stability, frequency, frequency time-keeping and harmonic content.

Power supply systems should be designed to afford isolation for maintenance of individual components without affecting the operation of the plant.

Where redundant UPS systems are specified, the segregation of redundant supply channels should be maintained throughout the installation.

On battery backed power supply systems, a battery low signal should be made available to the emergency shut-down system to allow a timely and orderly plant shut-down to be implemented.

Where the electricity supply is directly from the low voltage public distribution network, it should be confirmed that the instrumentation will work as intended with the voltage characteristics of the supply. The characteristics are given in BS EN 50160. Additional measures, e.g. surge protection, might be necessary at the installation.

Where a standby generator is used, earthing arrangements should in accordance with BS 7430.

17.4 Power supply sizing

Power supply systems should be sized initially to have 25% excess capacity to cater for design modifications. When first commissioned, the system should ultimately be capable of supplying at least 110% of the maximum design load in order to accommodate later minor additions. Spare circuits should be provided as appropriate throughout the distribution system to permit utilization of the spare capacity.

Battery float and boost charging facilities and capacities should allow for the worst conditions, e.g. minimum and maximum battery room ambient temperatures coupled with the worst simultaneous loading conditions, whilst maintaining the supply within the required parameters.

Any float charging system should be so designed that it can maintain full battery charge under all conditions of load.

17.5 Supply protection and isolation

All protective devices should have proven current/time characteristics.

Each circuit, subcircuit and control loop should be individually protected by its own fuse or miniature circuit breaker (MCB). However, where a control loop contains a number of items that can be used independently, consideration should be given to the protection and isolation of individual items.

Each shut-down device, system or actuator should generally be individually protected. Where a shut-down system comprises a number of actuating devices, and supply failure to part of a system rather than the whole system would itself create a hazard, the system rather than the individual items should be protected.

Isolation of each individual panel-mounted instrument should be provided by a double-pole switch, MCB, disconnecting plug or isolating terminals as appropriate. Supplies to non-critical panel instruments may be grouped (preferably not more than six) to one supply circuit.

The local power supply to each item of field-mounted equipment should have an individual isolator suitable for the zone classification of the area within which it is installed.

17.6 Intrinsically safe power supplies

*NOTE See also Clause **5**.*

Intrinsically safe equipment may be loop powered or may have a separate power supply.

Where the power supply to the hazardous area equipment is separate to the signal loop, a barrier or isolator should be installed in the power supply circuit to achieve conformity to the intrinsic safety design requirements in BS EN 60079.

18 Installation

18.1 Installation and documentation

Installation should be carried out by competent personnel using the best engineering practices. Contract documents should contain the following:

a) the scope of the work to be carried out and demarcation of responsibilities between the parties involved;

b) the extent of the material to be supplied;

c) drawings and documentation giving full details of installation requirements and references to the relevant standards that apply;

d) terms and conditions of contracts relating to the work on a particular project covering such things as workmanship, tidiness, safety and competency, i.e. when the work is to be carried out by a contractor or subcontractor.

WARNING. Existing plant might still have asbestos products present. Lead and other hazardous substances might also be present in plant. Attention is drawn to the Control of Asbestos Regulations 2006 [93], the Control of Lead at Work Regulations 2002 [94], the Control of Substances Hazardous to Health Regulations 2002 [95] and related legislation (see Table A.1).

18.2 Installation drawings

Provision should be made on a plant site for a drawing register to be maintained, and it is important that only the current editions of drawings which contain the latest revisions are used.

The drawings and documentation covering the instrument installation that should be provided for a specific project would, for example, comprise the following.

a) engineering flow diagrams: schematic drawings of the equipment, piping and control systems making up the plant or process which are sometimes referred to as P and I (piping and instrument) diagrams;

b) instrument schedule: lists of all instrument items by tag number and providing an index to the applicable purchase order requisitions, specifications and installation drawings;

c) instrument loop schematics: diagrams showing the connections between the components of instrument and control loops and identifying pneumatic and wiring connections, terminals, cables and core numbers (as applicable);

d) logic diagrams and control schematics: drawings showing the schematic logic of interlock and shut-down systems and special control circuits;

e) instrument location drawings: area layout drawings on which are shown the approximate location of instruments, tapping points, panels, control valves, etc., and the proposed routing of air headers, transmission tubing and wiring;

f) instrument installation details: hook-up drawings showing piping and mounting arrangements for the various instruments, with an itemized material list for each arrangement;

g) panel layout drawings: drawings showing the positions of instruments mounted on panels and overall panel dimensions;

h) panel piping and wiring diagrams: panel layout drawings showing the position and connections for incoming multicore tubes and/or cables;

i) control room layout drawings: drawings showing positions of control panels and auxiliary racks in the control room and the routing of connection tubes and/or cables;

j) multicore cable and tubing routing: overall plot plan showing the approximate locations of the main junction boxes and the routing of the multicores. Where applicable, cable trench cross-sections and cable tray layouts are also shown;

k) junction box layouts: drawings giving details of individual junction boxes showing the cabling connections, terminal details and identification;

l) cable/tubing schedules: lists of all instrument multicore cabling/tubing with lengths, sizes, connection points, core identification and relevant technical information;

m) installation material summary: details of the material quantities required for the installation of each instrument and the total quantities ordered or to be provided, which are sometimes referred to as MTO (material take off) or MR (material requisition), or BOQ (bill of quantities);

n) instrument specifications: technical specifications and design data for each instrument.

18.3 Instrument protection and storage

Instruments and panels that cannot be installed upon delivery should be housed in a properly constructed and heated store and protected from dust and damp. Manufacturers' storage recommendations should be sought prior to delivery of the equipment to site and manufacturers' specific requirements should be rigorously followed to avoid invalidating the equipment manufacturer's warranty.

Completion of control rooms should be programmed to permit the installation of panels immediately upon receipt and so minimize handling. If the control room heating system is not in operation, temporary heaters should be installed to ensure that the panels and instruments are kept warm, dry and condensation-free.

Throughout the construction period, and especially when instruments have been installed in the field before electrical power supplies are applied, instruments that are not provided with housings should be protected by covering with heavy duty plastics bags or where necessary by applying more robust protection.

18.4 Instrument mounting and accessibility

Each instrument or item of equipment to be installed should be inspected to check that its data plate agrees with the specification and that it has been pre-tested (see Clause **19**). The instrument should then be installed in its intended location, e.g. on brackets, sub-panel, mounting post or process connection, ensuring that it is levelled, vertically plumbed and firmly secured.

In all installations the manufacturer's specific requirements should be rigorously followed.

Where necessary, instruments should be secured to the nearest suitable firm steelwork or masonry so as to be, as far as possible, unaffected by vibration. Process lines or handrails should not be used for supporting instruments or their mounting stands.

Instruments should be located so that they do not obstruct walkways or equipment and so that they are afforded the maximum protection from damage that might be caused by passing or falling objects. They should also be clear of drainage points for condensate, water and process fluids from adjacent plant equipment.

All indicating instruments and instruments requiring adjustments should be accessible for servicing from floor level, walkways, permanent ladders or platforms.

NOTE 1 Attention is drawn to the Work at Height Regulations 2005 [30] and related legislation (see Table A.1).

NOTE 2 In some instances, portable platform access might be considered suitable.

Post-mounted instruments should be located at a height of between 1.2 m and 1.4 m above floor level or permanent platforms, unless site conditions dictate otherwise, e.g. a shorter post might be desirable where vibration could be a problem.

All indicating instruments should be readable from floor level or permanent platforms. Gauge glasses should be visible from access ladders and preferably visible from any control valve that controls the vessel level.

When locating post-mounted flowmeters for liquid or steam service, care should be taken to ensure that the elevation of the orifice installation is such that sufficient slope in the impulse piping is obtainable.

*NOTE 3 For additional considerations for control valve installations, see Clause **10**.*

Control valves should be accessible from floor level or permanent platforms. Clearance should be allowed above a control valve to allow for servicing of its actuator and also below for servicing the valve internals, where applicable. Suitable clearances should also be allowed to give access to manual handwheels and valve positioners.

Care should be taken in locating tapping points to keep the impulse lines as short as possible, at the same time enabling control instruments to be mounted as close as possible to their associated control valves.

Brackets and supports should be protected against corrosion, e.g. by adequate priming and painting. Where cable tray supporting steelwork or cable trays are cut or drilled, the exposed surfaces should also be primed and painted.

Mounting materials should be selected so as to prevent electrolytic corrosion.

Care should be taken to ensure that the forces developed by the expansion of piping or vessels will not damage instruments or impulse piping.

All pressure instruments fitted with blow-out vents should be mounted with a clearance of at least 25 mm between the vent and nearest obstructing surface, and be located so as not to endanger personnel.

On completion of installation, all field-mounted instruments, air header isolation valves, tubing and wiring terminations, should be identified by permanent labelling.

19 Testing and verification

19.1 Responsibility for testing and approval

NOTE 1 It is assumed that for each plant or section of a plant there will be a responsible engineer for the instrumentation representing the owner/operator who will be responsible for the work carried out on that plant.

NOTE 2 A list of typical test equipment is given in Annex B.

A test procedure should be developed and should be documented in accordance with Clause **6**. It should include a list of the test equipment required and its suitability should be agreed with the responsible engineer before any testing is commenced.

It is essential that all test equipment is approved by the responsible engineer and, where appropriate, its accuracy should be at least one order of magnitude better than the accuracies claimed by the manufacturer for all instruments that are to be tested.

All test equipment should have a valid calibration certificate issued by a recognized authority and should be periodically re-checked. The interval between checks should be agreed with the responsible engineer.

The test and calibration equipment should be calibrated in the units of measurement selected for and appropriate to the project, in accordance with manufacturer's instructions and to a traceable standard appropriate to the requirements of the equipment under test. All test equipment should be suitable for the environment in which it is to be used and should be approved by the responsible engineer.

Approval should be obtained from the responsible engineer before electric power or pneumatic supplies are applied to any panel or to any section of plant. On any plant, whether or not it is operating, it is essential to comply with any permit-to-work procedures that are in force (see **4.3**).

19.2 Testing before commissioning

Before commissioning (or start-up) of a new installation, the completed instrumentation and control equipment installation should be fully tested to ensure that the equipment is in full working order.

Instrument testing work should be carried out only by personnel that are fully skilled to do the work and, where unfamiliar specialized equipment is being installed, the testing personnel should be given supplementary training on that equipment.

For most plants, instrument testing comprises several stages as described in **19.3** to **19.9**.

On completion of each test, the stage of the testing procedure reached should be indicated by a temporary label affixed to each instrument or installation.

It is recommended that coloured labels are used to make identification easier. Suggested colours are shown in Table 7.

Table 7 **Test status colour code**

Colour	Meaning
Blue	Pre-installation tested
Yellow	Pressure tested
Green	Cables tested
Red	Pre-commissioned (ready for commissioning)
White	Test failed (written message may be added giving reason for failure)

Such identification should be shown on all components in the loop to enable personnel to see the current status of the installation.

When testing is finished, all connections and entries should be sealed temporarily so as to prevent moisture and dirt getting into the equipment.

A record of all test results should be made on a standard form and, when appropriate, approval signatures should be obtained (see **19.9**).

19.3 Software

All software supplied by a manufacturer should be verified as being uniquely labelled and dated in accordance with a version control system.

A site version control system should be applied in order to record software updates or modifications.

Software generated or modified on site should be referenced and subject to version control.

Device parameters and control configuration settings should also be referenced and subject to version control.

A software updating procedure should be established in order to ensure that any changes made as the commissioning proceeds are permanently recorded.

For data security reasons at least two copies of all records should be maintained and be accessible to the commissioning team. The second or back-up pack should be clearly labelled "Back-up". In addition, a master set should be held in a secure location in an area remote from the plant. These masters should be updated at intervals dictated by the rate at which changes are being made and should be clearly labelled "Master".

If a control system fails it is important, if the cause of the failure is to be identified, to record various system parameters. This is normally achieved by running a crash dump program prior to restarting the system. The procedure for running the crash dump program together with the restart procedure should be clearly defined and available to the commissioning team in order to enable a timely recovery from system crashes. Any crash should be recorded in the system log.

19.4 Inspection upon receipt

Immediately upon receipt on site, before any pre-installation testing is carried out, each item of equipment should be visually inspected to ensure that it conforms to the manufacturer's specification and is free from any defects. If any defects or deficiencies are found, these should be reported to the responsible engineer and remedial action agreed before the equipment is put in the stores.

19.5 Pre-installation testing

19.5.1 General

NOTE 1 For types of instrument not covered in detail in this British Standard, refer to the manufacturer's instructions.

All instrument equipment should be tested before it is installed to ensure that each individual instrument is functioning correctly and that it is accurately calibrated. The tests should be performed in accordance with the methods given in this subclause and any adjustments should be carried out in accordance with the manufacturer's instructions.

All tests should be made so as to simulate as closely as possible the design process values, by using manometers, potentiometers, resistance bridges, dead weight testers, test pressure gauges, etc., and hydraulic, electric and pneumatic supplies connected as appropriate (see **19.5.3**).

In general, all instruments should be kept at room temperature for a sufficient time for them to become stabilized before tests are carried out. It is recommended that electronic instrumentation should be energized for 24 h before testing.

All shipping stops should be removed from the instruments before proceeding with testing. Miscellaneous components, e.g. charts and oil, should be correctly installed.

The calibration of all instruments should be checked in both the upscale and downscale directions and, if necessary, adjustments made until their readings are within the accuracy limits stated by the manufacturer.

The results of each completed test should be recorded on the appropriate calibration sheet (see **19.9**) and witnessed by the responsible engineer.

The responsible engineer should be informed immediately and given written confirmation of any defects that cannot be rectified or of any instrument that cannot be calibrated within the time period specified by the manufacturer.

The written approval of the responsible engineer should be obtained before any non-standard modifications or adjustments are made.

Where the pre-installation test is not specified in the original designer's test schedule, or where circumstances prohibit the prescribed test being carried out, a suitable test method should be agreed with the responsible engineer. The fluid used during testing should be compatible with the process fluid.

NOTE 2 It is essential to drain the liquids used for testing the instruments as a precaution against damage caused by liquids expanding on freezing.

When the tests are complete, the instrument should be drained and, if necessary, blown through with clean, oil-free dry air or a fluid compatible with the process fluid. Where applicable, shipping stops should be replaced. After testing and draining, all connections and entries should be temporarily sealed to prevent subsequent ingress of moisture and dirt.

19.5.2 Pre-installation test procedures

NOTE It is preferable to carry out instrument testing in a calibration workshop, except where instruments form part of an integrated system or control panel, in which case tests may be carried out in the control room after installation by using portable test gear and/or simulation equipment.

The instrument to be tested should be mounted in the correct plane on a rigid and vibration-free stand or structure.

Before commencing any tests, checks should be carried out to ensure that:

a) the instrument is not damaged in any way, e.g. damage to doors and linkages. Any such damage should be rectified before any tests are attempted;

b) the data plate on the instrument agrees with the information contained on the instrument specification sheet;

c) the power source available, whether electrical or pneumatic, is that specified for the instrument;

d) any fuses fitted to electrical components are of the correct rating;

e) a suitable means is available for simulating the required process variable;

f) test gauges or meters of sufficient accuracy are available for the tests to be performed, and where appropriate test equipment accuracy is at least one order of magnitude better than the accuracy of the equipment being tested;

g) the manufacturer's instruction book is available.

19.5.3 Energy supply source and output

*NOTE The procedures described in **19.5.3.1** and **19.5.3.2** are common to all instruments requiring a power supply source and which generate a signal output.*

19.5.3.1 Pneumatic

The air supply for pneumatic instruments should be clean, dry and oil free.

The air supply should be connected and the air supply regulator adjusted to the correct setting (e.g. 1.4 bar [7]) for a standard transmitter with an operating range of 0.2 bar to 1.0 bar).

The output should be connected to a suitable test gauge via a capacity chamber (approximately 0.5 l capacity).

Care should be taken to ensure that all pneumatic connections are leak-free. To ensure a leak-free installation, the joints should be tested with soap solution or other suitable solution.

19.5.3.2 Electric/electronic

The power supply specified by the manufacturer of the instrument (shown on the data plate or documentation) should be connected. Electronic instruments should preferably be left energized for 24 h before beginning calibration tests.

Correct polarity of supply should be maintained at all times.

The output of the instrument should be connected to a suitable test meter, preferably a digital milliammeter or alternatively a digital voltmeter with suitable shunt resistor.

19.5.4 Process variable source

A suitable signal generating source, which can simulate the process, should be connected to the process connection, together with a means of isolating and regulating the connection, with a suitably accurate indicator. The process variable source will depend upon the type of signal to be simulated.

When an instrument is intended to be used with a process fluid that could present a hazard, suitable safety precautions should be observed and the test method agreed with the responsible engineer, e.g. for oxygen service testing fluids should be oil-free. After testing the instrument it should be thoroughly cleaned, dried and sealed together with a moisture absorbent in a protective polyethylene covering, and should remain sealed until required for installation.

The manufacturer's testing requirements should be rigorously followed, as there might be, for example, a static shift when the differential pressure measuring device is later connected to the process operating pressure.

19.5.5 Calibration test

19.5.5.1 General

This procedure should be carried out for all instruments (transmitting, receiving and direct reading) other than local pressure gauges, temperature indicators or switches (see **19.5.7** to **19.5.9**).

Where receiver instruments form part of a distributed system and where factory tests have been carried out, the testing procedure should be agreed with the responsible engineer.

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7) 1 bar = 10^5 N/m^2 = 100 kPa.

19.5.5.2 Leak test (pressure systems)

A maximum input pressure should be applied to the process connection, the inlet valve closed and the pressure source disconnected. The gauge on the inlet should be observed to ensure that there is no fall-off of pressure over a 3 min period. Where leaks are suspected, these should be eliminated and the test repeated.

If this kind of test is performed on a gas system, the gas temperature will change as gas is introduced into the system, especially if high pressures are involved. Thus, the pressure might rise before full temperature equilibrium is reached. In this case, sufficient time should be allowed for temperature equilibrium to occur before the 3 min inspection period begins.

19.5.5.3 Calibration

The instrument should be checked at zero reading and adjusted if necessary.

The process input signal should be increased and the corresponding output signal and/or scale readings recorded at 0%, 25%, 75% and 100% of the instrument range. The readings should always be taken when the signal is rising.

The process input signal should be decreased and the corresponding output signal and/or scale readings should be recorded again at 100%, 75%, 25% and 0% of the instrument range. The readings should always be taken when the signal is falling.

The percentage error calculated from these readings should not exceed the manufacturer’s stated limits for both accuracy and hysteresis.

Where necessary, adjustments should be made according to the manufacturer’s instructions and the tests repeated. Accuracy of readings should be better than, or equal to, the accuracy limits stated in the manufacturer’s specification.

After the tests have been completed, the instrument should be colour coded as recommended in **19.2**.

19.5.6 Controller functional test

19.5.6.1 General

This procedure should be carried out for discrete analogue controllers, either field-mounted or panel-mounted. It does not apply to microprocessor type controllers forming part of an integrated system, which are usually factory-calibrated and for which any field tests or adjustments are subject to special agreement with the responsible engineer (see **19.8.2**).

19.5.6.2 Receiver controllers (closed-loop method)

Receiver controllers, either pneumatic or electronic, should be tested by the closed-loop method. This entails connecting the controller output to the signal input connection via, in the case of pneumatic instruments, capacity chamber (e.g. 0.5 l) to give the system stability.

The following procedure should then be performed in order to check the controller alignment and synchronization.

a) The controller action should be set to reverse (decreasing output for increasing input) and the auto/manual transfer switch to auto.
b) The proportional band should be set to a low value.
c) Integral and/or derivative actions (if fitted) should be set to minimum time values.
d) The settings of any limits should be checked to allow full scale indication of the calibrated span.
e) The set-point should be adjusted to 50% of scale.
f) The controller output should now read 50% (e.g. 0.6 bar or 12 MA) or, if there is a deviation scale, it should be at null balance point (centre scale).
g) The set-point should be moved upscale and downscale whilst observing the output meter. The output meter should continuously track (follow) the set-point and the deviation indication should always read null. Sufficient time (about 3 min) should be allowed at each set-point setting to permit the controller to balance correctly.
h) With the controller set-point and output at 0% [see item f)], the proportional band setting should be moved from minimum to maximum. During this movement, the output and null balance reading should remain constant.
i) The auto/manual transfer switch should then be changed to manual, whence it should be possible to vary the output manually from 0% to 100% of the output scale.
j) In the event of the controller performing incorrectly, adjustments should be made in accordance with the manufacturer's instructions until satisfactory test results are obtained.
k) An actuating signal equivalent to 50% of the instrument range should be applied to the controller and the manual regulator output adjusted to 50%. The controller set-point should then be adjusted to 50%, and, by switching the auto/manual transfer switch, bumpless transfer should be confirmed. Where necessary, using the manufacturer's instructions, adjustments should be made to achieve satisfactory bumpless transfer.
l) After satisfactory completion of the above tests, the controller action should be returned to the correct mode required for service operation. The controller adjustments should be left with settings of 100% proportional band and minimum integral and derivative times.

The full calibration checking of proportional, integral and/or derivative functions is not normally required, but when specified these functions should be checked in accordance with the manufacturer's instructions.

19.5.6.3 Direct-connected controllers (open-loop method)

The following procedure should be performed.

a) For controllers connected directly to the process, the process variable should be simulated (see **19.5.4**). A suitable power supply should be connected. In the case of pneumatic controllers, a capacity chamber, e.g. 0.5 L, should be connected to the output to give the system stability. An output indicator should also be connected.

b) The controller action should be set to direct (to increasing output for increasing input) and the auto/manual transfer switch to auto.

c) The proportional band should be set to a low value.

d) The integral and/or derivative settings (if fitted) should be set to minimum time values. The settings of any limits should be checked to allow full-scale indication of the calibrated span.

e) The set-point should be adjusted to 50% of scale.

f) The process variable should be increased to 50% of scale, at which point the controller output should change from minimum to maximum. If this does not occur, adjustment should be made in accordance with the manufacturer's instructions.

g) When correct changeover occurs, the controller action should be reversed and the operation re-checked to ensure that the controller is correctly aligned. If not, adjustments should be made in accordance with the manufacturer's instructions and the test repeated.

h) Having checked the alignment as above, the controller action should be set to the required mode for operation, and the proportional band set to 100%.

NOTE The controller is normally synchronized at 50% of the output range (e.g. 0.6 bar or 12 MA) and should therefore indicate mid-output range when the set point and the process variable are at mid-scale.

i) The process variable and set-point should be set to 50% of scale.

j) With the controller set at 50% of scale as above, the proportional band setting should be adjusted from minimum to maximum, during which the output pointer should remain stationary.

k) In the event of the controller performing incorrectly, adjustments should be made in accordance with the manufacturer's instructions and the tests should then be repeated.

l) The auto/manual transfer switch should then be changed to manual whence it should be possible to vary the output manually from 0% to 100% of the output scale.

m) After satisfactory completion of the above tests, the controller action should be returned to the correct mode required for service operation. The controller adjustment should be left with settings of 100% proportional band and minimum integral and derivative times.

The full calibration checking of proportional, integral and/or derivative functions is not normally required, but when specified these functions should be checked in accordance with the manufacturer's instructions.

19.5.7 Pressure gauges

NOTE Vacuum gauges require the use of a vacuum test pump.

Pressure gauges should be checked by means of a hydraulic pressure gauge comparator against a standard test pressure gauge.

The gauge comparator should be firmly fixed to a bench. A test gauge of range comparable to the gauge under test should be fitted to one branch of the comparator. The gauge to be tested should be fitted to the other branch and the hand pump on the comparator operated in order to check the gauge against the readings of the test gauge.

Readings should be checked for pressures corresponding to 0%, 50% and 100% of the range of the gauge under test. Actual gauge readings should be noted for both rising and falling signals.

Test gauges should have an accuracy of or better than 0.25% of full scale and should be periodically checked for accuracy against a dead-weight tester.

19.5.8 Pressure switches

Pressure switches should be tested at their operating point using either a compressed air source or a dead-weight tester, depending upon the range of the pressure switch under test. A continuity test-circuit should be connected across the contacts to ensure correct operation.

Care should be taken to ensure that the switch operation is in the correct mode, i.e. with a rising or falling signal according to the instrument specification.

Where the switching differential is stated in the specification, this should also be checked.

19.5.9 Temperature indicators

19.5.9.1 Local

Local temperature indicators (dial thermometers) should be checked using a temperature bath. They should normally be checked at approximately 50% of the range unless otherwise agreed by the responsible engineer.

19.5.9.2 Remote

Remote temperature indicators working from RTDs should be checked using a decade resistance box and injecting the appropriate resistance values.

Remote temperature indicators working from thermocouple inputs should be tested using a millivolt source. Cold junction compensation should be taken into account.

19.5.10 Temperature switches

Temperature switches should be tested at their operating point using a temperature bath.

A continuity test circuit should be connected across the contacts to ensure correct operation.

Care should be taken to ensure that the switch operation is in the correct mode, i.e. with a rising or falling signal according to the instrument specification.

Where the switching differential is stated on the original design specification, this should also be checked.

19.5.11 Level switches

Float switches should be tested mechanically prior to installation with a continuity test circuit connected across the contacts to ensure correct operation. Care should be taken to ensure that the switch operation mode is correct.

19.5.12 Solenoid valves

An appropriate power supply should be connected via a switch.

An air supply should be connected to the appropriate port or ports.

The operation of the valve should be checked by operating the switch and observing correct changeover action.

The tightness of shut-off should be checked by connecting a flexible tube to the outlet port or ports and immersing the free end in water to ensure that the valve closure is bubble-tight at the stated design pressure.

Where applicable, electrical and manual reset, override and time delay features should be checked as indicated in the valve specification.

The resistance of the coil should be checked to ensure that it is as specified.

19.5.13 Flow devices

Flowmeters cannot usually be tested in the field. Testing should be carried out at an approved independent or manufacturer's test site, Pre-commissioning site tests should not be omitted, unless agreed with the responsible engineer and documented in accordance with Clause **6**.

Before installation, the flow device should be checked to ensure that the data and material specification stamped on the data plate or tab handle agrees with the specification. Orifice plates should be examined for flatness and to ensure that they are undamaged. The bore should be accurately checked to ensure that it agrees with the figure stamped on the tab handle.

19.5.14 Control valves

19.5.14.1 General

NOTE These tests may be carried out in the instrument workshop or, as is more often the case, in situ after the valve has been installed in the line.

Tests should not be carried out until the valve is in its final operating state, i.e. after line flushing operations have been completed.

Where line flushing and hydrostatic testing has occurred with the valve in situ, the valve stem packing should be checked and replaced if damaged.

The valve and data plate should be checked to ensure that they are in accordance with the control valve specification.

A check should be made that, where specified, a lubricator is fitted and is charged with the correct lubricant.

19.5.14.2 Diaphragm actuated valves without positioners

For diaphragm actuated valves without positioners, the following tests should be carried out.

a) A note should be made of the dry operating range (bench-set) of the diaphragm actuator from its data plate or specification sheet.

b) A suitable regulated air supply together with an accurate test gauge should be connected to the diaphragm case connection.

c) The air pressure should be increased to load the diaphragm, and the valve spindle position from the valve stem position indicator should be checked against the appropriate air pressure signal. The travel should be checked at 0%, 25%, 75% and 100% of the valve stroke.

d) Where necessary, the valve spring tension nut should be adjusted to obtain the correct start point and a retest carried out.

e) Where necessary, the speed of operation from fully open to fully closed should be checked to ensure that it is within the limits stated on the specification sheet.

f) Where necessary, the hysteresis should be checked by using a micrometer dial indicator clamped to the valve stem and repeating the travel test with rising and falling signals at 0%, 25%, 75% and 100% of the valve stroke. The hysteresis should be within 5% of the valve stroke unless otherwise specified in the original design specification.

NOTE For precautions to be taken when pressure testing, see ***4.13****.*

g) When tight shut-off is an important criterion, a test rig should be fabricated comprising a blind flange on the valve outlet fitted with a 6 mm bleed pipe and a suitably rated isolation valve from the centre of the flange. The open end of the bleed pipe should be immersed in a container of water so that discharge bubbles can be observed.

h) The specified signal corresponding to the valve closed position under normal operating conditions should be applied to the valve actuator and, if necessary, adjustments made to the valve, until the leakage bubble-rate is within the specified tolerance.

i) Where an air failure lock-up relay or other accessory device is incorporated, it should be checked for correct operation in accordance with the instrument specification.

19.5.14.3 Diaphragm-actuated valves with positioners

For diaphragm actuated valves with positioners, the following tests should be carried out.

a) Where the positioner is fitted with a bypass valve (normally omitted on split-range service [8)]), the valve should be switched to the bypass position and a variable air supply connected with test gauge to the signal input connection.

b) A note should be made of the dry operating range (bench-set) of the diaphragm actuator from its data plate or specification sheet.

c) The air pressure should be increased to load the diaphragm and the valve spindle position from the valve stem position indicator should be checked against the appropriate air pressure signal. The travel should be checked at 0%, 25%, 75% and 100% of the valve stroke.

d) Where necessary, the valve spring tension nut should be adjusted to obtain the correct start point and a retest made.

e) Where necessary, the speed of operation from fully open to fully closed should be checked to ensure that it is within the limits stated on the specification sheet.

8) For such valves see the manufacturer's instructions.

f) Where necessary, the hysteresis should be checked by using a micrometer dial indicator clamped to the valve stem and repeating the travel test with rising and falling signals at 0%, 25%, 75% and 100% of the valve stroke. The hysteresis should be within 5% of the valve stroke unless otherwise specified in the original design specification.

*NOTE For precautions to be taken when pressure testing, see **4.13**.*

g) When tight shut-off is an important criterion, a test rig should be fabricated comprising a blind flange on the valve outlet fitted with a 6 mm bleed pipe and a suitably rated isolation valve from the centre of the flange. The open end of the bleed pipe should be immersed in a container of water so that discharge bubbles can be observed.

h) The specified signal corresponding to the valve closed position under normal operating conditions should be applied to the valve actuator and, if necessary, adjustments made to the valve, until the leakage bubble-rate is within the specified tolerance.

i) The operating range of the positioner, input and output, should be recorded.

j) An air supply should be connected to the positioner supply connection and adjusted to 0.4 bar above the maximum operating rate of the actuator.

k) If fitted, the positioner bypass valve should be switched on.

l) A variable input source should be connected to the positioner signal connection.

m) The actuator should then be checked for travel, with rising and falling signals at 0%, 25%,75% and 100% of the valve stroke, against the appropriate air pressure signal. If necessary, adjustment should be made in accordance with the manufacturer's instructions, and a retest carried out.

19.5.14.4 Other actuators

Control valves with other types of actuators, e.g. piston operators, air cylinder operators, electro/hydraulic or electric motor operators, should be tested for stroking and failure action in accordance with the manufacturer's instructions.

Where limit switches or torque switches are fitted, these should be checked, using a continuity test set, for correctness of setting and for operation. On motorized valves, care should be taken to check the setting of the limit switches before switching on the actuator.

19.5.15 Safety valves

19.5.15.1 General

*NOTE 1 The testing of safety valves is sometimes outside the scope of work of the instrument installation contractor and the tests in this subclause are given as a guidance for use when required. There are two safety valve tests: popping and reseating (**19.5.15.3**) and seat leakage (**19.5.15.4**).*

NOTE 2 See BS EN ISO 4126-1 for further guidance.

Boiler safety valves are usually tested in situ after mounting on the boiler. The valve adjustment facility should be provided with a seal to prevent unauthorized interference.

All test methods should be agreed with the responsible engineer before being put into operation.

Safety valves should be stored in a secure warehouse with the valves standing vertically.

When received, the valve blanking plates should be checked for damage that could have allowed the passage of foreign material into the inlet nozzle and the body cavity.

Before testing, it should be ensured that the valve data plate agrees with its specification sheet, that the valve orientation is correct and that the direction of flow is clearly marked on the valve body.

Safety valves should be tested immediately prior to installation. If installation is deferred, the protective flange covers should be refitted and the valve stored in a vertical position. When required for service, the valve should be retested.

All tests on safety valves should be recorded on the check sheet (see **19.9**) and the signatures of witnesses should be obtained as required.

19.5.15.2 Test rig

Safety valves are normally tested in a workshop which should be equipped with a suitable test rig. The test rig user should check that there is no formation of rust or scale within the test rig which could be blown through into the valve under test. A suitable nozzle with gaskets, adaptor flanges and bolts or clamps should be incorporated so that the relief valve under test can be mounted rigidly in a vertical position.

Compressed air should wherever possible be used as a test fluid, but bottled inert gas may be used if air is not available at the required pressure. The test fluid should be filtered to ensure that no particles of foreign matter are passed through into the valve under test.

If a test gas other than air is used, the test rig should be installed in a freely ventilated location.

For high pressure duties, hydrostatic testing might be required using a purpose-built test rig, which should be operated in accordance with the manufacturer's instructions. On hydrostatic test rigs, all piping and fittings in contact with water should be of stainless steel.

To control the test pressure, a precision reducing valve and a test pressure gauge (minimum 150 mm diameter) with resettable maximum pointer should be provided on the inlet side. The reducing valve and gauge ranges should be selected to cover the range of safety valve set pressures to be tested.

19.5.15.3 Popping and reseating test

Before popping the safety valve, ensure that the outlet test flange has not been fitted and that the valve outlet is unobstructed.

The inlet nozzle should be wiped clean prior to testing.

The safety valve cold set pressure should be ascertained and entered on the test record sheet. This pressure will normally be found on the valve data plate or on the valve data sheet.

The test pressure should be increased slowly until the safety valve is observed to pop, and the pressure (as indicated by the maximum pointer on the test gauge) should be noted on the test record sheet. If the difference between the measured popping pressure and the cold set pressure is outside acceptable tolerances, the valve setting should be adjusted in accordance with the manufacturer's instructions.

The test pressure should then be lowered and the reseating pressure noted and checked to ensure that it agrees with the safety valve specification.

19.5.15.4 Seat leakage test

The seat leakage test should be carried out in accordance with BS EN ISO 4126-1.

19.6 Pressure testing of instrument piping and tubing

NOTE Attention is drawn to the Pressure Equipment Regulations 1999 [18], as amended (see Table A.1) and the Pipelines Safety Regulations 1996 [96].

19.6.1 General

All piping installations that come within the instrument contract should be tested to ensure that all instrument piping and tubing is pressure-tight under the specified working/testing conditions.

The pressure testing of any equipment fabricated on site, e.g. cooling chambers, capacity pots and catch pots, should be witnessed by the responsible engineer and test certificates provided.

The instrument piping and tubing to be tested can be classified in the following categories:

a) air supply piping (see **19.6.2**);

b) transmission signal tubing (see **19.6.3**);

c) process impulse piping (**19.6.4**).

The pressure testing of air supply piping, transmission tubing and process impulse pipework on a given loop should be completed before the final loop testing. Thus, if the transmitter has to be disconnected for loop testing, only one connection has to be rechecked.

19.6.2 Air supply piping

NOTE The testing of the main instrument air header from the source up to and including the first isolation, usually on the pipe track, is not included in this procedure.

For the air supply piping test it is assumed that the instrument air compressors and dryers have been commissioned and an instrument air supply established at the specified working conditions, i.e. clean, dry and oil-free. If the permanent air supply has not been established, an alternative source of clean, oil-free, dry air or nitrogen should be used, which can be obtained either from storage cylinders or an oil-free compressor with dryer.

The following procedure should be carried out.

a) Branch air lines to individual instruments should be disconnected immediately upstream of and adjacent to the instrument air fitter regulator and blown through with clean air until clear of all foreign materials. The tubing downstream of the filter regulator should be blown through before connection to the instruments and associated equipment.

b) The open end(s) should be blanked off and a suitable test pressure gauge connected into the system.

c) The isolation valve immediately upstream of the piping to be tested should be opened and when the line is pressurized it should be closed. This test should have a duration of 10 min and the test gauge should be observed in order to detect leakage. In addition, all joints should be checked for leaks by the application of soap or similar solution, and leaking joints remade as necessary.

d) On completion of the test, the line should be reconnected and the joint(s) that have not previously been proven should be checked with soap solution.

e) The pipe should then be colour coded as recommended in **19.2**.

19.6.3 Transmission signal tubing

The following procedure should be carried out.

a) Each individual tube should be disconnected at both ends and blown through with clean, oil-free, dry air.

b) The tubes should be blanked off and pressurized to 1.4 bar from an existing air supply, via a pneumostat or bubble bottle. After pressurizing, the bubble rate should be less than one bubble in 10 s.

NOTE 1 If an air supply is not readily available, the tubes may be pressurized using a foot pump and with a manometer connected into the system.

c) With the pressure source isolated, the reading should remain constant for a period of 10 min.

d) The tube should then be reconnected and, when an air supply is established, the joints that have not previously been proven should be tested with soap solution.

NOTE 2 This may be achieved by setting the transmitter/controller outputs to maximum.

e) Underground tubing should be tested before trench backfilling is commenced.

f) The tubing should then be colour coded as recommended in **19.2**.

19.6.4 Process impulse piping

The following procedure should be carried out.

a) After fabrication, where practicable, process impulse piping should be disconnected at both ends for flushing and testing.

b) The line should be flushed with water, then one end should be blanked off and the other end should be connected to a hydraulic pump with a suitable test gauge fitted. The line should next be pressurized to the test pressure of the associated process line or vessel. The line should then be isolated from the pressure source and the pressure should remain constant for a period of 10 min.

NOTE Test pressure is normally 1.5 times maximum working pressure or maximum design pressure.

c) After testing, the lines should be thoroughly dried out using dry air or nitrogen before being reconnected to the instrument manifold, and all manifold valves should be checked for tight shut-off.

d) For close-coupled instruments, e.g. line-mounted differential pressure cells, the pipes should be disconnected at the instrument only and tested up to the initial isolation as in **19.6.4**b).

e) During hydraulic tests on the main process line, instruments should be disconnected to ensure that initial isolations are leakproof. During flushing, all installed instruments should be positively isolated from the process line. Instruments fitted with manifolds should have their bypass lines open.

f) It should also be ensured that all instrument pressure tappings have been drilled through the pipe wall.

g) All instrument equipment and piping that has been hydrostatically tested with water or other fluid should be thoroughly dried out on completion of the test.

19.7 Testing of instrument cables

NOTE 1 Attention is drawn to the need to perform continuity and insulation resistance checks in accordance with BS 7671.

Immediately after cables are laid and before connection and termination, the interconnecting cabling in electrical and electronic instrument loops, i.e. all thermocouples, electrical and electronic instrument wiring, should be checked for polarity, continuity and insulation resistance between conductors and between conductors to earth. These tests should be carried out before final loop power-off tests.

CAUTION. Severe damage can be caused to barriers and electronic equipment if insulation testing of cables is carried out after connection.

Underground cables should be tested before trench backfilling is commenced.

NOTE 2 For instrumentation in hazardous areas, see Clause ***5****.*

Tests on instrument cables for loop impedance, inductance, capacitance, etc. should be carried out, where required, in accordance with BS EN 60079-14 in order to determine their suitability for inclusion in intrinsically safe circuits.

Coaxial cables used for data-highways should be tested using sine-wave reflective testing techniques.

After all tests have been completed, the cables should be colour coded as recommended in **19.2**.

19.8 Pre-commissioning (including loop testing)

19.8.1 General

All instrument systems and loops should be tested to ensure that they are in full operational order when connected together and are in a state ready for plant commissioning.

The completed instrument loop should be tested as one system and, where necessary, adjustments should be made to calibrations. Associated hardware and software alarms and trips should be checked during loop testing. Any adjustments necessary should be recorded.

All systems should be checked for correct operation.

As a prerequisite to testing, the measurement, monitoring and control equipment, inspection and testing of the associated pipework, wiring, mounting, etc. should be carried out to ensure that the installation is complete, conforms to the specific plant design and has been carried out in a professional manner and in accordance with this British Standard.

Checks for mechanical/electrical completeness should be carried out using the instrument loop check sheet (see Annex C).

19.8.2 Microprocessor systems

On site, testing and pre-commissioning of control room microprocessor control and monitoring systems is a specialist task and would usually be carried out by specialist personnel from the equipment manufacturer or, alternatively, other suitably qualified and experienced personnel. The manufacturer's instructions should be followed.

Every input and output signal should be checked through from its field initiation point to control room display unit or vice versa. All control functions should be checked for operability in accordance with the manufacturer's stated performance characteristics.

All test methods should be agreed with the responsible engineer.

19.8.3 Complex control systems

The procedures for the testing of complex control systems, e.g. multi-fuel combustion controls, should be agreed with the responsible engineer before the work begins. Moreover, complex interlocking and shut-down systems with many inputs and outputs require a carefully planned testing procedure which should also be formulated and agreed in advance.

Testing of emergency shut-down systems should involve physical operation of the actual shut-down devices, on both inputs and outputs.

19.8.4 Emergency shut-down systems

A specific procedure should be agreed in advance with all parties prior to testing of the emergency shut-down system. This procedure should cover, but not be limited to, the testing of each individual function, the sequence of functions, and the logic of the interaction.

A certified record of all tests should be kept.

19.8.5 Alarm systems

The hardware alarm monitoring system should be energized and the "test", "accept" and "reset" buttons operated to ensure that all display windows are functional and that the alarm sequence is operational.

The display facia should be checked to ensure that window colours and engravings are correct and located in the correct positions.

19.8.6 Loop testing procedure

The following procedure should be carried out for loop testing.

a) The instrument engineer responsible for loop testing should give adequate notice to representatives of other engineering disciplines where the tests are interrelated.

b) Loop testing should not be carried out on electronic equipment until an adequate warm-up period has elapsed. Where possible, the equipment should be energized for at least 24 h before testing.

c) The loop should be inspected and air/electrical supplies set where appropriate. In particular, the control valve air supply pressures should be checked to ensure that they are set in accordance with the manufacturer's specification.

d) For electronic loops, a check should be made to ensure the electrical polarities are correct. The loop impedance should be measured and the necessary compensating adjustments made.

e) Each loop should be tested from the field signal input through to the receiving instrument and, in the case of controllers, the output should also be checked through to the final control element operation. During a loop test, all ancillary items in the loop should be tested, e.g. hardware signal convertors, trip amplifiers and alarm switches, software trip actions and alarms.

f) Before loop testing, all components should be checked for correct zeroing and adjustments made if necessary.

   To carry out a loop test, it might be necessary to isolate the transmitter (or input device) from the process and to connect in a process signal simulator (see **19.5.4**). Signals should be generated equivalent to 0%, 50% and 100% of the instrument range, and the loop function checked for correct operation at each point in both rising and falling modes.

g) If errors in overall loop calibration are detected, repeat tests should be carried out on individual items of the loops as in **19.5**.

h) For controller applications, the controller should be switched to manual mode and, by applying the appropriate signals, it should be ensured that the control device operates correctly, e.g. control valve or valves stroke correctly. Valve positioner gauges should also be checked during this stage.

i) Both hardware and software alarm and trip actions should be checked by varying the actuating signals and adjusting as necessary.

j) Locally mounted controller or transmitting-only loops should be tested in a similar manner to that described in c) to i), omitting non-applicable checks as necessary.

k) After each loop is satisfactorily tested, the controller should be switched to manual and checked for the following:

   1) correct action selection;

   2) 100% proportional band;

   3) minimum integral action;

   4) minimum derivative action.

l) The monitoring or control loop should then be colour coded as recommended in **19.2**.

m) Upon completion, one copy of the test certificates for every loop installation, recording all of the equipment test results that form part of the loop, should be made available to the responsible engineer. The certificates for any tests not witnessed should be accompanied by the responsible engineer's written confirmation that witnessing has been waived.

19.8.7 Temperature loops (thermocouple and resistance thermometer)

NOTE For temperature loop simulation, signals from resistance thermometers are simulated by decade boxes and signals from thermocouples by the use of precision millivolt signal generating sources.

Thermocouples and resistance thermometers should be removed from their wells and checked to ensure that they are not damaged. The resistance of each resistance thermometer should be measured at ambient temperature, and both resistance and temperature should be noted.

After testing, all thermocouples/resistance thermometers should be replaced in their thermowells and reconnected. It is important to ensure that the element reaches the bottom of the thermowell and that the electrical polarity of the thermocouple connections are correct.

For galvanometer deflection type instruments using thermocouples, compensating lead resistances should be adjusted if necessary.

Where a two-wire resistance thermometer system is employed, make-up/ballast resistance should be adjusted.

For three- and four-wire resistance thermometer installations, care should be taken to ensure that the connections are according to the manufacturer's instructions.

All systems should be checked for correct operation, including the checking of burn-out features on thermocouple installations.

19.8.8 Process analysers and associated equipment

Process analysers should be checked according to the manufacturer's instructions and by agreement with the instrument engineer.

Trip and alarm actions not previously covered in the tests, e.g. initiating devices that stop/start pumps, should be checked in conjunction with the instrument engineer.

Process analyser systems are often complex and should be checked for correct operation, including the checking of burn-out features where measurement instrumentation such as thermocouples are an integral part of the analyser installation.

19.8.9 Preparation for commissioning

Upon completion of loop testing, the installation should be made ready for process commissioning. All extra work, such as setting zero elevations and suppressions, filling liquid seals, adjusting purge rates, etc., should be completed.

All accessories should be checked for completeness, e.g. fuses, safety-glasses, covers and enclosure doors should be fitted.

19.9 Check sheets

NOTE Examples of calibration and check sheets and a test report are shown in Annex C.

The results of all calibration checks and loop tests should be recorded on suitable check sheets, signed by the instrument engineer responsible for testing and countersigned by the responsible engineer.

20 Commissioning and acceptance

*COMMENTARY ON CLAUSE **20***
Commissioning is the bringing on-stream of a process plant and the tuning of all instruments and controls to suit the process operational recommendations. This clause is intended to form the basis of a plant instrumentation commissioning and acceptance procedure.

A plant, or section of a plant, is considered to be ready for commissioning when the following conditions are met:

*a) all instruments have been installed in accordance with the approved drawings and other relevant documentation prepared and supplied by the plant designer, instrumentation manufacturer or contractor (see Clause **18**);*

*b) the installation has been checked for mechanical/electrical completeness (see Clause **19**);*

c) all line flushing operations and pressure tests have been completed;

*d) all signal loops have been fully tested for electrical or pneumatic integrity (i.e. instrument pre-calibration and loop testing) as described in the pre-commissioning procedure (see Clause **19**);*

*e) the settings and set-points of all controllers and alarm initiators have been adjusted to estimated values and the correct operation of all instruments has been demonstrated to the satisfaction of the operator (see Clause **19**);*

f) the labelling of all instruments and connections has been completed to the satisfaction of the operator;

g) the site or area has been cleaned up, i.e. all surplus materials and tools have been removed, and all painting and thermal installation work has been completed, unless otherwise agreed by the operator.

*NOTE Before the introduction of process material or commencing work in or adjacent to a live plant, on any area not yet commissioned, it is essential that permit-to-work procedures in force are complied with (see **4.3**).*

20.1 Commissioning

20.1.1 General

All pertinent documents, including flow diagrams, flow data, schedules of safety valve settings, alarm settings and controller set-points, should be available at all times for use by the commissioning engineers.

During the plant commissioning period, specialist and instrumentation engineers should be in attendance until the official handover and acceptance of plant has taken place.

Stores and workshops should be available during the commissioning period. Consumable spares should be available at all times. A procedure should be in place to record all items withdrawn from the stores.

During commissioning, all errors, omissions and alterations to the installation, whether due to design changes or for any other reason, should be carefully noted and remedial action agreed in writing with the operator before work commences.

20.1.2 Preliminary checks

As a prerequisite to instrument commissioning, the commissioning engineers should ascertain, as a minimum, that:

a) all instrument electrical power supplies are fully functional, including any emergency standby supplies;

b) all instrument air supplies are available;

c) all liquid seals are installed and filled in accordance with the design requirements;

d) all control valve lubricators have been charged with the correct lubricant;

e) all protective heating systems, e.g. heat tracing and heated enclosures, are working, where required;

f) the control room environment is satisfactory and in a finished state;

g) control room air conditioning systems are fully operational and are maintaining correct temperature and humidity conditions;

h) all cable entries to control rooms have been sealed.

20.1.3 Commissioning procedures

20.1.3.1 General

Instrument commissioning should be carried out on a loop-by-loop basis and should be fully coordinated with the plant start-up operations.

Before commissioning an instrument loop, all instrument zeros should be checked and adjusted where necessary, i.e. for both transmitting and receiving instruments.

Commissioning falls into several main phases as described in **20.1.3.2** to **20.1.3.5**.

20.1.3.2 Measurement systems

All instruments requiring power supplies should be energized, e.g. remote transmitters.

Electronic instruments should where practicable be energized for at least 24 h, and in accordance with the manufacturer's instructions, before commissioning is commenced in order to provide an adequate warm-up period. Where the warm-up period is not allowed, settings might need to be checked and readjusted at a later stage. Where adjustments are necessary, these should be recorded.

Pressure sensing systems or impulse lines should be pressurized by gradually opening the process block valves at the primary sensing points. Bleed/vent valves should be opened as necessary during pressurization in order to eliminate air, unwanted gases or condensate from the process sensing lines.

Differential pressure systems, e.g. flow and liquid level, should be pressurized in the same way, taking care to observe the correct valve opening sequence in accordance with the manufacturer's instructions.

Read-out instruments (indicators and recorders) should be observed to check that appropriate readings are being obtained.

Recorder chart drives should be energized and recording mechanisms should be in operation.

20.1.3.3 Control systems

Before attempting to commission a control loop, all the required air, fluid and electrical power supplies should be available at all loop components, e.g. transmitter, controller and control valve positioner, if fitted.

The initial stages of plant commissioning are usually accomplished with controllers switched to the manual bypass mode and with control valves manually bypassed in the field by operation of bypass valves, by operation of manual hand wheels, or by manually derived signals from the controller.

When a control valve is on manual bypass in the field, the control valve actuator should first be pressurized by a remote signal derived from the controller in manual mode, and then the control valve should be brought into operation by removing the manual override constraints.

With the controller still in the manual mode, the responsiveness of the system should be checked by varying the remote manual signal and observing the response on the read-out instrument, taking care to avoid causing upsets which could be detrimental to process operations. To avoid plant upsets, the likely interaction of one plant control loop with another via the process material should be established before commissioning begins.

NOTE For methods of controller tuning, see the manufacturers' instructions.

Once the system is seen to respond correctly and the required process variable reading is obtained using remote manual control, the controller set-point should be aligned with the process variable and the controller should, with the operator's agreement, then be switched to auto in order to bring the controller on-stream.

The controller responses, i.e. proportional, integral, and derivative actions, should then be adjusted to obtain optimum settings to suit the automatic operation of the plant.

20.1.3.4 Alarm systems

Alarm hardwired annunciator systems should be energized and the test button/s operated to ensure that all display windows are functional.

Alarm sensing primary elements should be commissioned, one at a time, as described in **20.1.3.2**.

After commissioning, the alarm settings should be checked to ensure that they are operating at the values specified at the original design stage.

20.1.3.5 Shut-down systems

NOTE Often a plant is commissioned with a limited number of shut-down inhibit switches, relative to that part of the plant being commissioned, in an override position, as it is sometimes impracticable to have function trips in operation when attempting to commission the plant.

Shut-down systems should have all inputs and outputs functionally tested at the plant pre-commissioning phase (see Clause **19**).

Before attempting to commission a shut-down system on a plant it is essential to formulate a commissioning procedure in conjunction with the process operation personnel, and reach written agreement regarding operation of any inhibit switches.

The primary measuring instruments associated with shut-down systems should be energized and commissioned as described in **20.1.3.2**. Once the plant is on-stream the inhibit switches should be changed to auto operation, step by step, as soon as possible.

Before overriding any of the shut-down systems, the written agreement of the plant operation supervisor should be obtained.

20.2 Acceptance

All instrumentation should be complete and shown to be working to the satisfaction of the plant operator before the plant take-over and acceptance certificates are prepared.

When requested, the acceptance procedure should provide for the handover of all drawings, data sheets, check lists, test results, manufacturers' and suppliers' operating and maintenance instructions/manuals, quality assurance/quality control reports, as-built drawings, etc., prepared during the original design and the construction of the plant.

The final acceptance certificate should be issued and certified only when all control loops and individual instrument systems have been demonstrated to work satisfactorily and have been formally accepted by the plant operator.

If, at the time of final acceptance, certain items are still pending due to unforeseeable reasons, they should be carefully listed and agreed between the parties involved. Agreement should also be reached concerning the method of completing the work and the time for its completion.

Annex A (informative) Guidance on legislation

A.1 Guidance on specific regulations

NOTE In many cases there are separate regulations for Northern Ireland, and in some cases for Scotland as well. These are listed in Table A.1 but are not referred to individually in the subclauses that follow.

A.1.1 Health and Safety at Work etc. Act 1974 and Management of Health and Safety at Work Regulations 1999

The Health and Safety at Work etc. Act 1974 [1] applies to all industries and provides a broad framework within which health and safety at work can be regulated. The Management of Health and Safety at Work Regulations 1999 [2] set out general duties that apply to almost all work activities. Under this legislation, employers have a duty to consult with their employees or their safety representatives on matters relating to health, safety, and welfare at work, including any change that might substantially affect health and safety at work, e.g. in procedures, technology, equipment or ways of working, arrangements for provision of competent help in satisfying health and safety law, the planning of health and safety, and the information to be provided on the likely risks and dangers arising from work, methods to eliminate or reduce those risks and procedures for dealing with a risk or danger.

Under this legislation, the responsibility for ensuring safe methods of working and operating equipment rests primarily on the employer or occupier but is not restricted to those persons. There is also an obligation on all agents, workers and employed persons to carry out their work in accordance with the statutory requirements and relevant site regulations. In particular, employees are required:

- to take reasonable care for their own health and safety and that of others who might be affected by what they do or do not do;
- to cooperate with their employer on health and safety, taking steps to understand the hazards in the workplace and complying with the safety rules and procedures;
- to correctly use work equipment, including protective clothing or equipment (PPE) provided by their employer or used in the workplace;
- to be familiar with and adhere to safety signs;
- not to interfere with or misuse anything provided for health, safety and welfare of anyone in the workplace or the general public.

A.1.2 Reporting of Injuries, Diseases and Dangerous Occurrences Regulations 1995

The Reporting of Injuries, Diseases and Dangerous Occurrences Regulations 1995 [9] require employers, the self-employed and persons in control of work premises to take the following actions:

- in the case of death or major injury (including as a result of physical violence) of any person working on their premises, or of a member of the public being killed or taken to hospital, notify the appropriate enforcement authority without delay;

- for an over three-day injury (including as a result of physical violence) to any person working on their premises, report on the appropriate form to the enforcing authority;
- report to the enforcing authority any work-related disease of an employee that has been notified by a doctor.

If something happens that does not result in a reportable injury, but which clearly could have done, it might be a dangerous occurrence and has to be reported immediately to the enforcement authority, followed within ten days by a completed accident report form.

A.1.3 Provision and Use of Work Equipment Regulations 1998

The Provision and Use of Work Equipment Regulations 1998 [13], as amended (see Table A.1), apply to all work equipment in workplaces and work situations where the Health and Safety at Work etc. Act 1974 applies, and extends outside Great Britain to certain offshore activities in British territorial waters and on the UK Continental Shelf. They do not apply to ships, except where the ship's equipment is used by other than the master or crew, or where the master and crew are involved with the work and other people are put at risk. They might also apply to work equipment not belonging to but used on board a ship by persons other than the master and crew, e.g. contractors carrying out work in territorial waters.

The Regulations do not apply to employees, but to employers and the self-employed who provide equipment for use at work or control the use of the equipment.

Equipment provided for use at work is required to be suitable for the intended use, safe for use, maintained in a safe condition, which in certain circumstances requires inspection, accompanied by suitable safety measures, e.g. protective devices, markings, warnings, and only be used by people who have received adequate information, instruction and training. The Regulations also require work equipment to conform to the essential requirements of all relevant European Union Directives that apply to it, as implemented by national regulations, when first put into use.

Under PUWER, employers are required to take appropriate measures, other than the use of personal protective equipment (see **A.1.9**) or provision of information, instruction and training, to prevent, or adequately control, specific hazards arising from the use of work equipment, including any article or substance falling or being ejected from work equipment, rupture or disintegration of parts of work equipment, work equipment catching fire or overheating, the unintended or premature discharge of any article or of any gas, dust, liquid, vapour or other substance, which, in each case, is produced, used or stored in the work equipment, the unintended or premature explosion of the work equipment or any article or substance produced, used or stored in it.

A.1.4 Electrical Equipment (Safety) Regulations 1994

The Electrical Equipment (Safety) Regulations 1994 [16] apply to almost all electrical equipment, but not generally to components, placed on the market that is designed or adapted for use between 50 V and 1 000 V a.c. (75 V and 1 500 V d.c.).

Suppliers of the equipment have a statutory duty to ensure that electrical equipment is safe. Manufacturers, or their authorized representative established in the European Economic Area (EEA), have the primary duty for designing and manufacturing the equipment to comply with the Regulations, for affixing the required CE marking and drawing up and holding the technical documentation and a DoC at the disposal of the regulatory authorities. Where the manufacturer is not in the EEA and has no authorized representative in the EEA, the person who imports the equipment into the EEA has a duty to keep the documentation and DoC at the disposal of the regulatory authorities.

Electrical equipment is required to be safe and to provide protection against all hazards arising from it and all hazards caused by external influences on it for persons, domestic animals and properties. Manufacturers are required to provide instructions for safe installation and use.

A.1.5 Supply of Machinery (Safety) Regulations 1992

NOTE The Supply of Machinery (Safety) Regulations 2008 [97] are expected to replace the existing regulations with effect from December 2009.

The Supply of Machinery (Safety) Regulations 1992 [17] , as amended (see Table A.1), apply to machinery, which is defined as "an assembly of linked parts or components, at least one of which moves, with the appropriate actuators, control and power circuits, etc, joined together for a specific application, in particular for the processing, treatment, moving or packaging of a material". Also covered are "an assembly of machines which, in order to achieve the same end, are arranged and controlled so that they function as an integral whole" and "interchangeable equipment modifying the function of a machine which is placed on the market for the purpose of being assembled with a machine (or a series of different machines) by the operator himself in so far as this equipment is not a spare or a tool".

All relevant machinery is required to conform to a comprehensive set of essential health and safety requirements, which cover a "danger zone" within and/or around machinery in which an exposed person is subject to a risk to personal health and safety. Certain types of high-risk machinery require third-party intervention. All relevant machinery is required to be safe.

The 1994 Amendment to the regulations introduced a specific reference to "safety components sold separately". This included components that are not interchangeable equipment which are placed on the market to fulfil a declared safety function the malfunctioning of which endangers the safety or health of exposed persons.

A consolidation of the European legislation is implemented by the 1995 Amendment, which also increases penalties, but it permits continued reference to the replaced European legislation in the deliverable documentation.

There are a number of specific exclusions, including for machinery where the risk is mainly electrical, which is covered by the Electrical Equipment (Safety) Regulations 1994 [16] (see **4.4.4** and **A.1.4**). Other exclusions that might be relevant to instrument personnel are steam boilers, tanks and pressure vessels, machinery designed for nuclear purposes, which, in the event of failure, can result in a release of radioactivity, radioactive sources forming part of a machine, storage tanks and pipelines for petrol, diesel fuel, inflammable liquids and dangerous substances and seagoing vessels and mobile offshore units together with equipment on board such vessels or units.

Electrical equipment designed or adapted for use below 50 V d.c. (75 V a.c.) might be subject to the Supply of Machinery (Safety) Regulations 1992 if it fits the definition and presents any of the listed hazards.

A.1.6 Pressure Equipment Regulations 1999

The Pressure Equipment Regulations 1999 [18], as amended (see Table A.1), apply to manufacturers of pressure equipment and assemblies, and cover the design, manufacture and conformity assessment of pressure equipment and assemblies subject to an internal pressure greater than 0.5 bar, such as vessels and pressurized storage containers, piping, heat exchangers, shell and water tube boilers, industrial piping, safety accessories. and pressure accessories. Vessels are housings designed and built to contain fluids under pressure, including attachments, and can be composed of more than one chamber. Piping is components intended for the transport of fluids when connected together for integration into a pressure system. Safety accessories are devices designed to protect pressure equipment against the allowable pressure limits being exceeded. Pressure accessories are devices with an operational function and having pressure-bearing housings. Assemblies are several pieces of pressure equipment assembled by the manufacturer to constitute an integrated and functional whole.

European Commission (EC) guidance is that the term "pressure bearing housing" refers to an envelope in which fluid under pressure (PS > 0.5) is contained or transported (volume V > 0). Therefore, a product whose only pressure-bearing surface is a flange or screwed fitting is not a pressure accessory (e.g. level switch, flush-mounted pressure transmitter, thermowell) but is a component of an item of pressure equipment under the Pressure Equipment Directive (97/23/EC) [98] when used on such equipment. The material requirements of the Regulations therefore apply.

NOTE Safety accessories are required to have a (over-pressure) detection and mitigation function. Therefore a pressure transmitter alone cannot be a safety accessory.

Pressure equipment and assemblies subject to the Regulations might contain components that have not been placed on the market as safety or pressure accessories. The manufacturer of the equipment/assembly has to ensure their suitability for use in the global conformity assessment of the equipment/assembly.

EC guidance is that individual piping components, such as a pipe or system of pipes, tubing, fittings, expansion bellows, hoses, or other pressure bearing components are not "piping". However, a single pipe, or a system of pipes, for specific application, can be classed as "piping", provided that all appropriate manufacturing operations such as bending, forming, flanging and heat treatment, have been completed. Some piping components (e.g. expansion joints) can be considered to be pressure accessories.

Pressure equipment and assemblies are classified depending on pressure/volume (PV) thresholds and the type and state of fluid. Above specified PVs, they are required to meet safety requirements covering design, manufacture and testing, otherwise they only have to be designed and manufactured to sound engineering practice (SEP). Except for equipment manufactured and designed to SEP, they are required to have the CE marking, appropriate documentation and identification of the responsible person, established in the EEA, placing it on the EEA market. SEP equipment has to be provided with suitable instructions for use and have the responsible person identified; it cannot have the CE marking.

A pressure equipment manufacturer has to classify the equipment into one of five categories, SEP or categories I, II, III or IV, depending on maximum allowable pressure, on whether it is a vessel, piping, steam generator, safety accessory or pressure accessory and on the state of the contents and the fluid group. There are two fluid groups: fluid group 1 is dangerous substances and group 2 is all other substances, including steam. Safety accessories are either the same category of the pressure equipment/assembly they are protecting, or category IV.

There are a number of specific exclusions in the Regulations. Some that might be of interest to instrument personnel are simple pressure vessels, networks for the supply, distribution and discharge of water, equipment that could cause a discharge of radioactivity, well-control equipment (including the well-head, blow out preventers, piping manifolds and all upstream equipment), equipment where pressure is not a significant factor in the design of the casing, blast furnaces for casting of steel and non-ferrous metals, mobile offshore units and equipment covered by international conventions. Equipment that is no higher than category I is also excluded if it is covered by the Supply of Machinery (Safety) Regulations 1992 (as amended) [17], the Electrical Equipment (Safety) Regulations 1994 [16], or the ATEX Regulations [19].

A.1.7 Equipment and Protective Systems Intended for Use in Potentially Explosive Atmospheres Regulations 1996

The Equipment and Protective Systems Intended for Use in Potentially Explosive Atmospheres Regulations 1996 [19] (ATEX Regulations), as amended (see Table A.1), cover electrical and mechanical equipment, protective systems, safety devices, components and their combinations, which, separately or jointly, are intended for the generation, transfer, storage, measurement, control and conversion of energy and/or the processing of material and which are capable of causing an explosion in a potentially explosive atmosphere through their own sources of ignition. They can be inside or outside the potentially explosive atmosphere, but are required to contribute to the safe functioning of equipment and protective systems with respect to the risk of explosion. The Dangerous Substances and Explosive Atmospheres Regulations 2002 [35] (see **A.1.15**) require zoned areas to be protected by selection of equipment and protective systems meeting the requirements of these Regulations.

The ATEX Regulations apply to mines, surface and offshore fixed installations endangered by potentially explosive atmospheres.

Equipment is divided into groups and categories depending on the location, nature and frequency/duration of the potentially explosive atmospheres for which it is to be used and whether it is required to continue operating. Most, but not all, equipment is subject to third-party assessment /certification procedures. Equipment and protective systems, but not components, are required to have the CE marking. There is also a requirement for specific markings (see Clause **5**).

Equipment specifically excluded, which might be relevant to instrument personnel, is equipment and protective systems where the explosion hazard results exclusively from the presence of explosive substances or unstable chemical substances, personal protective equipment for use in hazardous areas and seagoing vessels and mobile offshore units together with such equipment on such vessels or units.

Seagoing vessels and mobile offshore units are covered by the International Maritime Organisation (IMO) Convention.

A.1.8 Radio Equipment and Telecommunications Terminal Equipment Regulations 2000

The Radio Equipment and Telecommunications Terminal Equipment Regulations 2000 [20] apply to:

- telecommunications terminal equipment, which is communication equipment intended to be connected directly or indirectly by any means whatsoever to interfaces of public telecommunications networks;
- radio equipment that is capable of communication by means of the emission and or reception of radio waves utilizing the spectrum 9 kHz to 3 000 GHz propagated in space without artificial guide.

Radio equipment is required to avoid harmful interference to the air waves, and telecommunications terminal equipment is required not to harm the telecommunications network or cause an unacceptable degradation of the network and incorporates safeguards to protect personal data and privacy of the user. All equipment is required to display prominently, on it or in accompanying documentation, information pertinent to its intended use, and to be accompanied by a declaration of conformity to the applicable essential requirements. Some equipment is specifically excluded because it is covered by other legislation, such as marine civil aviation and air traffic management equipment and systems. Radio equipment only intended to receive sound or TV broadcasting services is also excluded.

The Radio Equipment and Telecommunications Terminal Equipment Regulations 2000 apply to most RTTE equipment likely to be installed by instrument personnel. Radio equipment is required to be suitable for the country in which it is intended to be used, i.e. the user manual for equipment suitable for use in the UK is required to contain a "GB" code. Telecommunications terminal equipment is required to have sufficient information to identify the interfaces of public telecommunications networks to which it can be connected.

A.1.9 Personal Protective Equipment at Work Regulations 1992

Under the Personal Protective Equipment at Work Regulations 1992 [24], as amended (see Table A.1), employers (including the self-employed) are required to provide PPE free of charge where there are risks to health and safety that cannot be adequately controlled by other means. They are required to provide PPE that is suitable for controlling the risks to health and safety, ensure that the PPE is suitable for the user in the conditions in which it is to be used, ensure that PPE is properly maintained, provide proper storage facilities for PPE and ensure that employees are adequately instructed and trained in the safe and proper use of any PPE required for their work.

A.1.10 Manual Handling Operations Regulations 1992

The Manual Handling Operations Regulations 1992 [25], as amended (see Table A.1), apply to manual handling operations that could cause injury at work. Employers are required to reduce risks from manual handling.

Management personnel are required to ensure that if manual lifting is needed, the weight and bulk of the equipment, the nature of the lift, the environment in which the lift has to take place and the stature of the person(s) performing the lift have been taken into account in the required risk assessment.

The Manual Handling Operations Regulations 1992 cover the lifting, lowering, pushing, pulling, carrying or moving of loads, whether by hand or by other bodily force. Employers are required to identify such operations under the Management of Health and Safety at Work Regulations 1999 [2] and to reduce any risk as far as reasonably practicable. Where manual handling cannot be avoided, a detailed risk assessment is required. This has to take into account the load, the working environment and individual capability, and to be completed by competent persons. They are required to have knowledge and experience of the Regulations, the nature of the handling operation, a basic understanding of human capabilities, identification of high-risk activities and practical steps to reduce risk.

A.1.11 Lifting Operations and Lifting Equipment Regulations 1998

The Lifting Operations and Lifting Equipment Regulations 1998 [28] (LOLER), as amended (see Table A.1), apply to all operations and equipment involved in lifting people and goods in all workplaces. Equipment covered includes new, second-hand or leased cranes, lifts, hoists, chains, ropes, slings, hooks, shackles, eyebolts, rope and pulley systems and forklift trucks. The Provision and Use of Work Equipment Regulations 1998 [13], as amended (see **A.1.3** and Table A.1), also apply to this equipment.

Employers are required to ensure that equipment has adequate strength and stability for each load, particularly with regard to mounting or fixing points. All foreseeable failure modes have to be considered and appropriate safety factors applied. Factors affecting stability also have to be considered. Lifting equipment and lifting accessories have to be clearly marked to indicate their safe working load and be thoroughly examined before being put into use for the first time and at regular intervals. Examination reports have to be in writing and be retained for specific periods. Where equipment requires an EC Declaration of Conformity, it has to be made not more than 12 months before the equipment is put into service. Equipment designed for lifting persons is required to be clearly marked as such, and equipment that is not designed for lifting persons but might be used in error is required to be clearly marked as not designed for lifting persons. All lifting operations have to be planned and supervised by a competent person, who has the same responsibilities as the employer.

Employers and the self-employed have a duty to ensure that all lifting equipment has adequate strength and stability for its proposed use, is marked to indicate its safe working load and is examined or inspected at regular intervals. They are also required to ensure that lifting equipment is examined before being put into use for the first time, plan all lifting operations, using a competent person, and ensure that all lifting operations are appropriately supervised.

A.1.12 Work at Height Regulations 2005

The Work at Height Regulations 2005 [30] apply to places "at height" in the workplace if a person could be injured falling from them, even if is at or below ground level. This includes moving about in a workplace, except by a staircase in a permanent workplace. The Regulations cover existing places of work and means of access or egress for work at height, collective fall prevention measures of protection (e.g. guard rails and toe boards), working platforms, collective fall arrest equipment (e.g. nets and airbags), personal fall protection (e.g. work restraints, work positioning, fall arrest and rope access) and ladders and stepladders. The Regulations mainly concern employers, the self-employed and those who control others working at height. However, there are mandatory requirements on employees and anyone working at height under someone else's control to report any safety hazard to them. They are also required to use the equipment in accordance with training and instructions. If they think it is unsafe they are not allowed to use it without seeking further instructions.

There are some exceptions for shipping, offshore installations, docks and people and organisations acting in the interests of national security, who can be exempted by the Secretary of State for Defence.

Duty holders are required to do all that is reasonably practicable to prevent anyone falling, taking account of all relevant risks, including weather conditions where relevant, ensuring that those involved in work at height are trained and competent and the work is properly planned and organised, and all equipment for work at height is appropriately inspected. There is a hierarchy for selecting equipment: collective protection measures then personal protection measures.

Inspection requirements apply to each individual place at which work is done at height, and equipment used for work at height. Regular inspections are required, which have be produced by competent persons. The competent person is required to produce a written report within a specified time, and the report then has to be kept for a specified period.

A.1.13 Workplace (Health, Safety and Welfare) Regulations 1992

The Workplace (Health, Safety and Welfare) Regulations 1992 [3] include requirements for safe access and egress to workplaces that are not domestic premises and are made available to any person as a place of work. Any room, lobby, corridor, staircase, fixed ladder, doorway, gateway, loading bay or ramp, road (other than a public road) or other place used as a means of access or egress from a workplace is classified as a "traffic route" and is covered by the legislation, whether for pedestrians, vehicles or both. Excluded are a number of workplaces covered by other regulations, such as building and engineering construction works, ships, docks, and mineral exploration and extraction sites.

Traffic routes are required to have floors or surfaces with no hole or slope, and are prohibited from being uneven or slippery to an extent that could expose persons to a health or safety risk. Suitable handrails (and guards if appropriate) have to be provided on staircases, unless they will cause an obstruction to the traffic route. As far as is reasonably practicable, the surface of every traffic route is required be kept free from obstructions and from any article or substance that could cause a person to slip, trip or fall.

A.1.14 Health and Safety (Safety Signs and Signals) Regulations 1996

The Health and Safety (Safety Signs and Signals) Regulations 1996 [32] apply to safety signs and signals in the workplace, whether it is a signboard, a safety colour, an illuminated sign, an acoustic signal, a verbal communication or a hand signal. Specifically excluded are signs used in connection with the supply of any dangerous substance, preparation, product or equipment (unless relevant legislation refers to these Regulations), to dangerous goods being transported by road, rail, inland waterway, sea or air, and normal ship-board activities of a ship's crew under the direction of the master. The Regulations include all the signs and signals covered.

All signs incorporating a safety colour (red, yellow/amber, blue or green) have to be a specific design.

- Prohibition signs are round and contain a black pictogram on a white background, with red edging and a diagonal line. The red part has to take up at least 35% of the area of the sign.
- Warning signs are triangular and contain a black pictogram on a yellow background with black edging. The yellow part has to take up at least 50% of the area of the signs.
- Mandatory signs are round and contain a white pictogram on a blue background. The blue part has to take up at least 50% of the area of the sign.
- Emergency escape and first-aid signs are square or rectangular and contain a white pictogram on a green background. The green part has to take up at least 50% of the area of the sign.

*NOTE The warning sign for places where explosive atmospheres might occur is not in the Health and Safety (Safety Signs and Signals) Regulations 1996 [32], but takes the same form as warning signs in them. The requirements are in the Dangerous Substances and Explosive Atmospheres Regulations 2002 [35] (see **A.1.15**).*

A.1.15 Dangerous Substances and Explosive Atmospheres Regulations 2002

The Dangerous Substances and Explosive Atmospheres Regulations 2002 [35] apply to most workplaces where there is a risk of fire or explosion from dangerous substances, including new and existing workplaces. They generally apply to employers and the self-employed, with some exceptions, but employees also have some responsibilities.

The Regulations address risks to safety in the workplace arising from dangerous substances and preparations. In this context premises covered are vehicles, vessels, land-based or offshore installations, moveable areas to which employees have access while at work and means of access and egress from the workplace. The latter includes common parts of shared buildings and private roads and paths on industrial estates and business parks. Also covered are dry-docks, harbours, naval bases and workplaces controlled by the Ministry of Defence. Specific exclusions include certain ship activities affecting only the crew and master, domestic activities, certain quarrying, mining and offshore activities covered by other regulations, transport by air, land or water covered by international regulations, and areas used directly for and during the medical treatment of patients.

The Regulations address certain harmful physical effects, including thermal radiation affects (burns), over-pressure effects (blast injuries) and oxygen depletion effects (asphyxiation) from fires, explosions and other energetic events such as runaway exothermic reactions or decomposition of unstable substances. Natural sources of dangerous substances are included.

Duty holders are required to perform a risk assessment at all workplaces where there are dangerous substances and preparations, taking account of the risks to all persons that could be affected, not just employees on the site. The risk assessment has to be reviewed periodically and before any new work is started, and retained where there are five or more employees.

The person or organization carrying out the risk assessment is required to be competent in the field of explosion protection and assessing the risks and adequacy of control and other measures put in place. If there are more than four employees in the workplace, the risk assessment significant findings have to be recorded as soon as practicable after the assessment has been made. Mitigation measures consistent with the risk assessment have to be applied, which can include preventing the spread of fire, reducing to a minimum the number of employees expose to the hazard and, in the case of process plant, providing plant and equipment that can safely contain or suppress an explosion, or vent it to a safe place.

The Health and Safety Commission's approved supply list covers dangerous substances and preparations under the Chemicals (Hazardous Information and Packaging for Supply) Regulations 2002 [99] (CHIP), for which the supplier is required to provide a data sheet. Other substances and preparations, whether in solid, liquid or gaseous form, whether naturally occurring or produced in a chemical or manufacturing process, waste products and products occurring in accident conditions, are dangerous if their physical and chemical properties and the way they are used or are present in the workplace causes a hazard.

Containers and pipes containing hazardous substances are required to be marked with signs with the same colours and symbols as in CHIP, but have the triangular shape for warning signs as in the Health and Safety (Safety Signs and Signals) Regulations 1996 [32].

Employers are required to conduct an assessment to establish risks to workers and any others who might be affected by their work or business which might arise because of the presence of dangerous substances or preparations at the workplace.

Employers are required to put in place plant equipment, work control measures, e.g. permit-to-work system, and supervision commensurate with the risks to health and safety. They are required to observe principles of good practice and ensure that workplace exposure limits are not exceeded.

Employers are required to ensure that, where possible, containers (any fixed or portable, open or enclosed, means to contain dangerous substances such as tanks, silos, reaction vessels, and waste receptacles) and associated piping are marked with warning signs identifying the hazard. The signs on pipes are required to be positioned at particular points such as valves and joints and at reasonable intervals. Where this is not possible, e.g. where contents change regularly in a process or the contents are only there for a short period of time, other means of identification and warning are required to be employed, such as employee training and site safety instructions.

Identification is not necessary for bulk solid products that are not dangerous in themselves, and are only hazardous when released and dispersed in the air.

A.1.16 Control of Vibration at Work Regulations 2005

NOTE 1 For work equipment first provided before 6 July 2007, the limit values are not applicable until 6 July 2010 (6 July 2014 for whole-body vibration in agriculture and forestry).

NOTE 2 BS EN ISO 5349-1:2001, relating to measurement and evaluation of human exposure to hand-transmitted mechanical vibration, and ISO 2631-1:1997, relating to measurement and evaluation of human exposure to whole-body mechanical vibration and shock, are directly referred to in the Regulations.

The Control of Vibration at Work Regulations 2005 [36] lay down minimum requirements for the protection of workers from hand-arm and whole-body vibration in the work place. Hand-arm vibration comes from the use of hand-held power tools, whilst whole-body vibration comes from riding in vehicles, particularly over rough terrain, such as in the mining, construction and quarrying industries.

To comply with the Regulations, employers have to perform a risk assessment. Where there is a risk from exposure to vibration an employer has to:

- reduce exposure to a minimum;
- provide information and training;
- assess exposure levels;
- carry out a programme of measures to reduce exposure and provide health surveillance when exposure reaches an exposure action value;
- keep exposure below an exposure limit value.

Assuming an 8 h working day, exposure values are:

- hand-arm vibration:
  - exposure action value 2.5 m/s^2 A(8);
  - exposure limit value 5.0 m/s^2 A(8);
- whole-body vibration:
  - exposure action value 2.5 m/s^2 A(8);
  - exposure limit value 5.0 m/s^2 A(8).

A.1.17 Control of Noise at Work Regulations 2005

NOTE ISO 1999:1990 is directly referred to in the Regulations.

The Control of Noise at Work Regulations 2005 [37] impose duties on employers and on self-employed persons to protect both employees who might be exposed to risk from exposure to noise at work, and other persons at work who might be affected by that work.

The Regulations cover the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (noise). They apply to all activities in which workers are likely to be subjected to risks from noise because of their work. Sea-going vessels are included, but the requirement to ensure that employees are not exposed to noise above an exposure limit value does not apply until 6 April 2011.

In the Regulations, there is an upper exposure limit and two exposure action values. Each has a daily exposure limit value and a peak sound pressure value. These are:

a) exposure limit values: daily limit 87 dB(A) and peak 200 Pa;

b) upper exposure action values: daily limit 85 dB(A) (90 dB(A) in previous Regulations) and peak 140 Pa (200 Pa in previous Regulations);

c) lower exposure action values: daily limit 80 dB(A) (85 dB(A) in previous Regulations) and peak 112 Pa.

Where daily noise varies considerably weekly noise exposure levels are permitted, provided 87 dB(A) is not exceeded.

Employers are required to have a risk assessment, at suitable intervals, by "competent services". They are required to retain it and keep it up to date. Wherever possible, they are required to reduce noise by technical means, i.e. by choice of equipment; working methods, layout of work places, information and training, workplace noise reduction techniques, maintenance programmes and organization of work.

If the upper exposure action values are exceeded, employers are required to:

- instigate a technical programme to reduce the noise;
- provide warning signs;
- provide PPE (ear protectors) and ensure they are worn;
- provide medical checks by suitably qualified medical persons, and retain medical records.

If the lower exposure action values are exceeded, employers are required to:

- provide PPE (ear protectors) and make every effort to ensure they are worn;
- provide preventive audiometric testing, and keep the records.

A.1.18 Confined Spaces Regulations 1997

The Confined Spaces Regulations 1997 [42] impose requirements and prohibitions with respect to the health and safety of persons carrying out work in confined spaces, but do not apply to activities on-board ship, below ground at a mine or to certain diving operations. They apply to Great Britain and some activities in territorial waters that are covered by the Health and Safety at Work etc. Act 1974 [1].

Employers are required to inhibit work in confined spaces, e.g. by working outside them, unless it is not reasonably practicable. If work has to be done in confined spaces, it has to be carried out in accordance with a safe system of work and only when rescue arrangements are in place in the event of an emergency. The rescue arrangement are not allowed to put rescuers at risk, so far as is reasonably practicable. Resuscitation equipment has to be made available and be maintained. HSE has the power to grant, in writing, exemptions from the Regulations, which can include conditions.

A.1.19 Pressure Systems Safety Regulations 2000

NOTE 1 The Pressure Equipment Regulations 1999 (as amended) [18] do not cover steam below 0.5 bar, but PSSR does.

NOTE 2 The Pressure Equipment Regulations 1999 (as amended) [18] give definitions of piping and pressure accessories, which are within the definition of piping in PSSR.

The Pressure Systems Safety Regulations 2000 [45] (PSSR) are intended to prevent serious injury from failure of a pressure system or one of its component parts. They are concerned with steam at any pressure, gases which exert a pressure in excess of 0.5 bar above atmospheric and fluids that can be mixtures of liquids, gases and vapours where the gas or vapour phase can exert a pressure of 0.5 bar above atmospheric. The Regulations do not consider the hazardous properties of the contents released following system failure, except for the scalding effect of steam. Also, they do not apply because of pressure exerted by a head of liquid and vacuums.

The Regulations include protective devices, which are any protective control or measuring equipment that is essential to prevent a dangerous situation arising. Instrumentation and control equipment is classified as a protective device if it has to function correctly in order to protect the system or where it prevents safe operating limits being exceeded. Suitable measuring/indicating instruments are required to give indications of critical conditions and safe operating limits and their displays have to be clearly visible. Gauge glasses on water level gauges have to be protected to prevent inquiry from the glass breaking. Materials used in construction have to be suitable for their intended use.

Employers have a duty to ensure that nothing in the way in which a pressure system is installed will give rise to danger or impair the operation of any protective devices or inspection facility. They are required to ensure that those doing the installation have the required training, skills and experience, that they are adequately supervised by competent persons, and that on completion the installation work is checked and approved by a suitably qualified person.

The attributes and roles of competent persons depend on the size and complexity of a pressure system. Pressure systems are classified in three categories, minor, intermediate and major.

- Minor systems are those containing steam, pressurized hot water, compressed air, inert gases or fluorocarbon refrigerants, which are small and present few engineering problems.
- Intermediate systems include the majority of storage systems.
- Major systems are those that because of their size, complexity or hazardous contents require the highest level of expertise, e.g. steam generators with individual capacities of more than 10 MW.

The Regulations only apply to pipelines in an installation (factory, process plant, onshore terminal. Pipelines outside an installation are covered by the Pipelines Safety Regulations 1996 [96] (PSR), for which guidance is given in HSE publication L82 [100].

A.1.20 Electricity at Work Regulations 1989

The Electricity at Work Regulations 1989 [47] apply to employers, the self-employed, mangers of mines and quarries and employees. They do not apply to the master or crew of a sea-going ship carrying out normal ship-board activities, nor to any person in relation to any aircraft or hovercraft moving under its own power.

Every employee has a duty to cooperate with their employer in complying with the Regulations. All others to which the Regulations are applicable have a duty to ensure the adequacy of the construction and maintenance of electrical systems, the controls for carrying out work on or near electrical systems, particularly when live, the training and competency of persons working on or near electrical systems or supervising such work, the measures for disconnecting the supplies, and the protective equipment supplied, including PPE (see **A.1.9**).

A.1.21 Health and Safety (Display Screen Equipment) Regulations 1992

The Health and Safety (Display Screen Equipment) Regulations 1992 [54], as amended (see Table A.1), give the minimum requirements for work with display screen equipment. Employers are required to assess the health and safety risks to employees habitually using display screen equipment in the course of their work and reduce them to the lowest extent reasonably practicable. They are required to provide initial eye and eyesight tests on request and at regular intervals thereafter, with the user's consent. Work has to be planned to ensure that breaks or changes in activity can be taken, and employees have to be adequately trained on health and safety issues concerned with the use of display screen equipment.

A.1.22 Construction (Design and Management) Regulations 2007

The Construction (Design and Management) Regulations 2007 [55] entered into force on 6 April 2007. The key aim of the Regulations is to integrate health and safety into the management of projects and to encourage everyone involved to work together to improve the planning and management of projects, from the design concept onwards.

There are two types of construction projects under the Regulations, notifiable and non-notifiable, with the former being those that are likely to involve more than 30 days or 500 person days of construction work. All of the Regulations apply to notifiable projects, whilst a limited number apply to non-notifiable projects. In both cases, duties are placed on clients, designers and contractors, which include requirements to ensure competency of, cooperation with and coordination of all persons covered by the Regulations.

- A client is any person who carries out a project personally, or, in the course or furtherance of a business, seeks or accepts the services of another to carry out a project for on his/her behalf. Duties are to:
    - ensure that arrangements for managing the project are suitable to ensure that the construction work can be carried out safely, so far as is reasonably practicable, that appropriate welfare facilities are provided, and that the design of any structure to be used as a workplace has taken account of the Workplace (Health, Safety and Welfare) Regulations 1992 [3];
    - provide pre-construction information to every designer and contractor pertaining to health and safety of persons engaged in the construction work and who will use the structure as a workplace.

- A contractor is any person who, in the course or furtherance of a business, carries out or manages construction work. Duties are to:
  - not carry out construction work unless the client is aware of their duties under the Regulations;
  - plan, manage and monitor the construction work to ensure that, as far as is reasonably practicable, there is no risk to health and safety;
  - ensure that all workers under his control and appropriately informed and trained to carry out their tasks without risk to health and safety;
  - not begin work on the site until reasonable steps have been taken to prevent unauthorized access;
  - ensure, so far is reasonably practicable, welfare facilities are maintained throughout the construction phase.
- A designer is any person who, in the course or furtherance of a business, prepares or modifies a design or arranges for or instructs any person under their control to do so. Duties are to:
  - not carry out construction work unless the client is aware of his duties under the Regulations;
  - avoid foreseeable risks to the health and safety of persons carrying out the construction work or liable to be affected by it;
  - take account of the Workplace (Health, Safety and Welfare) Regulations 1992 [3] relating to the design of, and materials used in, structures for use as workplaces;
  - take reasonable steps to provide sufficient information for clients, designers and other contractors to comply with their duties.

Where a project is notifiable, the client also has a duty to appoint a CDM coordinator then a principal contractor, which introduces further duties on the client, the designers and the contractors.

The CDM coordinator has to:

- be provided with appropriate pre-construction information by the client, including all health and safety information in the client's possession, to enable the CDM's duties to be carried out;
- have information from the designer to adequately assist in the carrying out of duties. The designer has to take reasonable steps to provide this, and is also not allowed to commence work (other than initial design) until a CDM coordinator has been appointed;
- provide suitable advice and assistance to the client on the measures to be taken to comply with the Regulations;
- make and implement arrangements for coordination of health and safety measures during planning and preparation for the construction phase;
- liaise with the principal contractor on the requirements of the health and safety plan and the information needed for the construction phase plan;

- take reasonable steps to ensure that duty holders have the pre-construction information relevant to their needs, ensure cooperation between the designers and the principal consultant, ensure that the health and safety file is available and maintained, and, at the end of the construction phase, pass the file to the client;
- notify HSE of his/her appointment, together with the required information, as soon as practicable, and of the appointment of the principal contractor when made.

The principal contractor has to:

- prepare a construction phase plan that complies with the Regulations. The client has to ensure that the construction phase does not start until the plan is available and he/she is satisfied that the requirements for welfare facilities have been complied with;
- in addition to the general contractor's duties, liaise with the CDM coordinator, give reasonable directions to other contractors, consult with other contractors before finalizing parts of the construction phase plan relevant to them, and provide information to allow other contractors to do their work without, as far as practicable, risks to health and safety;
- identify any risks to health and safety arising from the construction work and take suitable measures to address them;
- make and maintain arrangements which will enable the principle contractor and the workers engaged in the construction work to cooperate effectively on health and safety, consult with workers or their representatives on health and safety, and ensure that workers or their representatives can inspect any copy relating to the planning of the project that may health, safety or welfare, albeit with some specific exceptions.

A.2 Relationship between UK regulations and EC Directives

NOTE Table A.1 reflects the regulations that were current at the time of publication of this edition of BS 6739. The list is non-exhaustive.

Table A.1 gives a summary of the statutory regulations referred to in this British Standard, together with details of the EU Directives implemented by these regulations. It also includes details of amending regulations, and of equivalent regulations (where applicable) in Scotland and Northern Ireland.

Table A.1 **Summary of statutory regulations referred to in this British Standard, with details of related EC Directives**

Title	Statutory Instrument (SI) reference	National implementation of EU Directive (where applicable)
Chemicals (Hazardous Information and Packaging for Supply) Regulations 2002 [99]	SI 2002 No. 1689	92/32/EEC [101] amending for the 7th time 67/548/EEC [102], in so far as its provisions relate to the classification, packaging and labelling of dangerous substances, 1999/45/EC [103], 76/769/EEC [104], Annex I points 29, 30 and 31 (as amended by 2001/41/EC [105]), 91/155/EEC [106], 91/410/EEC [107], 92/37/EEC [108], 93/21/EEC [109], 93/72/EEC [110], 93/101/EC [111], 93/112/EC [112], 94/69/EC [113], 96/54/EC [114], 97/69/EC [115], 98/73/EC [116], 98/98/EC [117], 2000/32/EC [118], 2000/33/EC [119], 2001/58/EC [120], 2001/59/EC [121] Articles 1.1 and 1.5, 2001/60/EC [122], and 2006/8/EC [123]
Chemicals (Hazard Information and Packaging for Supply) Regulations (Northern Ireland) 2002 [124]	SR 2002 No. 301	92/32/EEC [101] amending for the 7th time 67/548/EEC [102], in so far as its provisions relate to the classification, packaging and labelling of dangerous substances, 1999/45/EC [103], 76/769/EEC [104], Annex I points 29, 30 and 31 (as amended by 2001/41/EC [105]), 91/155/EEC [106], 91/410/EEC [107], 92/37/EEC [108], 93/21/EEC [109], 93/72/EEC [110], 93/101/EC [111], 93/112/EC [112], 94/69/EC [113], 96/54/EC [114], 97/69/EC [115], 98/73/EC [116], 98/98/EC [117], 2000/32/EC [118], 2000/33/EC [119], 2001/58/EC [120], 2001/59/EC [121] Articles 1.1 and 1.5, and 2001/60/EC [122]
Chemicals (Hazard Information and Packaging for Supply) (Amendment) Regulations 2008 [125]	SI 2337 No. 2008 (SI 2002/1689 as amended by S.I. 2004/568, S.I. 2004/3386, S.I. 2005/2092, S.I. 2005/2571 and S.I. 2008/960)	2006/8/EC [123]and correcting errors implementing 92/32/EEC [101] and 1999/45/EC [103]
Chemicals (Hazard Information and Packaging for Supply) (Amendment) Regulations (Northern Ireland) 2005 [126]	SR 2005 No. 463	67/548/EEC [102] as amended by 2004/73/EC [127]
Confined Spaces Regulations 1997 [42]	SI 1997 No. 1713	Points 6.2 and 6.3 of Part A of Annex IV to 92/57/EEC [128]
Confined Spaces Regulations (Northern Ireland) 1999 [129]	SR 1999 No. 13	Points 6.2 and 6.3 of Part A of Annex IV to 92/57/EEC [128]

Table A.1 **Summary of statutory regulations referred to in this British Standard, with details of related EC Directives** *(continued)*

Title	Statutory Instrument (SI) reference	National implementation of EU Directive (where applicable)
Construction Products Regulations 1991 [91]	SI 1991 No. 1620	89/106/EEC [130]
Control of Asbestos Regulations 2006 [93]	SI 2006 No. 2739	The Regulations, with the exception of Regulations 4, 5, 11, 12, 20 and 21(5) to (7), implement as respects Great Britain 76/769/EEC [104] as amended by 83/478/EEC [131] insofar as it relates to the labelling of products for use at work containing asbestos, 83/477/EEC [132] as amended by 91/382/EEC [133] except insofar as this Directive was implemented by the Asbestos (Prohibitions) Regulations 1992 [134] (S.I. 1992/3067), 90/394/EEC [135] insofar as it relates to asbestos, and 98/24/EC [136] insofar as it relates to risks to health from exposure to asbestos.
Control of Asbestos Regulations (Northern Ireland) 2007 [137]	SR 2007 No. 31	See the Control of Asbestos Regulations 2006 [93].
Control of Asbestos at Work Regulations 2002 [138]	SI 2002 No. 2675	See the Control of Asbestos Regulations 2006 [93].
Control of Asbestos at Work Regulations (Northern Ireland) 2003 [139]	SR 2003 No. 33	—
Control of Lead at Work Regulations 2002 [94]	SI 2002 No. 2676	The Regulations, with the exception of regulations 4, 7, 8, 9(2) and (3) and 10(7) and (11) to (15), implement as respects Great Britain 98/24/EC [136] insofar as it relates to risks to health from exposure to lead.
Control of Lead at Work Regulations (Northern Ireland) 1998 [140]	SR 1998 No. 281	82/605/EEC [141] in part
Control of Lead at Work Regulations (Northern Ireland) 2003 [142]	SR 2003 No. 35	The Regulations, with the exception of regulations 4, 7, 8, 9(2) and (3) and 10(7) and (11) to (15), implement 98/24/EC [136] insofar as it relates to risks to health from exposure to lead.
Control of Noise at Work Regulations 2005 [37]	SI 2005 No. 1643	2003/10/EC [143]
Control of Noise at Work Regulations (Northern Ireland) 2006 [144]	SR 2006 No.1	2003/10/EC [143]

Table A.1 **Summary of statutory regulations referred to in this British Standard, with details of related EC Directives** *(continued)*

Title	Statutory Instrument (SI) reference	National implementation of EU Directive (where applicable)
Control of Substances Hazardous to Health Regulations 2002 [95]	SI 2002 No. 2677	The Regulations, with the exception of regulations 8, 9, 11(8), (10) and (11) and 14, implement as respects Great Britain, 78/610/EEC [145], Point 3 of Article 1 of 89/677/EEC [146] insofar as that point relates to the importation, supply or use of benzene and substances containing benzene for such purposes, 90/394/EEC [135] insofar as it relates to carcinogens other than asbestos, that part of 96/55/EC [147] adapting to technical progress for the second time Annex I to 76/769/EEC [104], 98/24/EC [136] insofar as it relates to risks to health from exposure to substances other than asbestos or lead, and 2000/54/EC [148]. The Regulations are consistent with the provisions of 91/322/EEC [149].
Control of Substances Hazardous to Health Regulations (Northern Ireland) 2003 [150]	SR 2003 No. 34	The Regulations, with the exception of regulations 8, 9, 11(8), (10) and (11) and 14, implement 78/610/EEC [145], Point 3 of Article 1 of 89/677/EEC [146] insofar as that point relates to the importation, supply or use of benzene and substances containing benzene for such purposes, 90/394/EEC [135] insofar as it relates to carcinogens other than asbestos, that part of 96/55/EC [147] adapting to technical progress for the second time Annex I to 76/769/EEC [104], 98/24/EC [136] insofar as it relates to risks to health from exposure to substances other than asbestos or lead, and 2000/54/EC [148]. The Regulations are consistent with the provisions of 91/322/EEC [149].
Control of Substances Hazardous to Health Regulations (Northern Ireland) 1995 [151]	SR 1995 No. 51 as amended by SR 1995 No. 60 as amended by SR 1998 No. 67	That part of 96/55/EC [147] amending 76/769/EEC [104] and 91/156/EEC [152], and 91/689/EEC [153] amending 75/442/EEC [154]
Control of Substances Hazardous to Health (Amendment) Regulations 2003 [155]	SI 2003 No. 978	Paragraphs 2 to 4 of Article 1 of 1999/38/EC [156]
Control of Substances Hazardous to Health (Amendment) Regulations (Northern Ireland) 2003 [157]	SR 2003 No. 288	Paragraphs 2 to 4 of Article 1 of 1999/38/EC [156]

Table A.1 **Summary of statutory regulations referred to in this British Standard, with details of related EC Directives** *(continued)*

Title	Statutory Instrument (SI) reference	National implementation of EU Directive (where applicable)
Control of Substances Hazardous to Health (Amendment) Regulations (Northern Ireland) 1999 [158]	SR 1999 No. 36	—
Control of Vibration at Work Regulations 2005 [36]	SI 2005 No. 1093	2002/44/EC [159]
Control of Vibration at Work Regulations (Northern Ireland) 2005 [160]	SR 2005 No. 397	2002/44/EC [159]
Construction (Design and Management) Regulations 2007 [55]	SI 2007 No. 320	92/57/EEC [128]
Construction (Design and Management) Regulations (Northern Ireland) 2007 [161]	S.R. 2007 No. 291	92/57/EEC [128] except certain requirements for work at height
Control of Major Accident Hazards Regulations 1999 [10]	SI 1999 No. 743	96/82/EC [162], known as the Seveso II Directive
Control of Major Accident Hazards Regulations (Northern Ireland) 2000 [163]	SR 2000 No. 93	96/82/EC [162]
Control of Major Accident Hazards (Amendment) Regulations 2005 [164]	SI 2005 No. 1088	2003/105/EC [165]
Control of Major Accident Hazards (Amendment) Regulations (Northern Ireland) 2005 [166]	SR 2005 No. 305	2003/105/EC [165]
Dangerous Substances and Explosive Atmospheres Regulations 2002 [35]	SI 2002 No. 2776	98/24/EC [136], so far as it relates to safety, and 99/92/EC (ATEX 137) [167]
Dangerous Substances and Explosive Atmospheres Regulations (Northern Ireland) 2003 [168]	SR 2003 No.152	98/24/EC [136], so far as it relates to safety, and 99/92/EC [167]
Electrical Equipment (Safety) Regulations 1994 [16]	SI 1994 No. 3260	73/23/EEC [22], as amended by 93/68/EE [169] and codified by 2006/95/EC [23]
Electricity at Work Regulations 1989 [47]	SI 1989 No. 635	—
Electricity at Work Regulations (Northern Ireland) 1991 [170]	SR 1991 No.13	—
Electromagnetic Compatibility Regulations 2006 [21]	SI 2006 No. 3418	2004/108/EC [171]

Table A.1 **Summary of statutory regulations referred to in this British Standard, with details of related EC Directives** *(continued)*

Title	Statutory Instrument (SI) reference	National implementation of EU Directive (where applicable)
Environmental Permitting (England and Wales) Regulations 2007 [61]	SI 2007 No. 3538	87/217/EEC [172], 92/112/EEC [173], 94/63/EC [174], 96/61/EC [175] as amended, 1999/13/EC [176] as amended, 1999/31/EC [177] as amended, 2000/53/EC [178] as amended, 2000/76/EC [179], 2001/80/EC [180], 2002/96/EC [181] as amended and 2006/12/EC [182]
Equipment and Protective Systems Intended for Use in Potentially Explosive Atmospheres Regulations 1996 [19]	SI 1996 No.192	94/9/EC [183] (ATEX 100A)
Equipment and Protective Systems Intended for Use in Potentially Explosive Atmospheres (Northern Ireland) 1996 [184]	SR 1996 No. 247	94/9/EC [183]
Equipment and Protective Systems Intended for Use in Potentially Explosive Atmospheres (Amendment) Regulations 2005 [185]	SI 2005 No. 830	94/9/EC [183] as amended by 83/189/EEC [186] and 98/34/EC [187]
Equipment and Protective Systems Intended for Use in Potentially Explosive Atmospheres (Amendment) Regulations 2001 [188]	SI 2001 No. 3766	Corrigendum 26/1/2000 to 94/9/EC [183]
Equipment and Protective Systems Intended for Use in Potentially Explosive Atmospheres (Amendment) Regulations (Northern Ireland) 1999 [189]	SR 1999 No. 125	94/9/EC [183]
Health and Safety at Work etc. Act 1974 [1]	1974 c 37	—
Health and Safety at Work (Northern Ireland) Order 1978 [190]	S.I. 1978/1039 (N.I. 9) as amended	—
Health and Safety at Work etc. Act 1974 (Application outside Great Britain) Order 1995 [191]	SI 1995 No. 263	—
Health and Safety at Work (Amendment) (Northern Ireland) Order 1998 [192]	SI 1998 No. 2795 (N.I. 18)	—
Health and Safety at Work (1998 Order) (Commencement) Order (Northern Ireland) 1999 [193]	SR 1999 No. 96 (C. 12)	—

Table A.1 **Summary of statutory regulations referred to in this British Standard, with details of related EC Directives** *(continued)*

Title	Statutory Instrument (SI) reference	National implementation of EU Directive (where applicable)
Health and Safety at Work etc. Act 1974 (Application outside Great Britain) Order 2001 [194]	SI 2001 No. 2127	—
Health and Safety at Work Order (Application to Environmentally Hazardous Substances) Regulations (Northern Ireland) 2003 [195]	SR 2003 No. 52	94/55/EC [196], 94/63/EC [174], 96/35/EC [197], 96/49/EC [198], 96/86/EC [199], 96/87/EC [200], 1999/47/EC [201], 1999/48/EC [202], 2000/61/EC [203], 2000/62/EC [204], 2001/6/EC [205] and 2001/7/EC [206]
Health and Safety at Work etc. Act 1974 (Application to Environmentally Hazardous Substances) (Amendment) Regulations 2004 [207]	SI 2004 No. 463	1999/45/EC [103], 2000/18/EC [208], 2003/28/EC [209] and 2003/29/EC [210]
Health and Safety (Display Screen Equipment) Regulations 1992 [54], as amended by the Health and Safety (Miscellaneous Amendments) Regulations 2002 [211]	SI 1992 No.2792	90/270/EEC [212]
Health and Safety (Display Screen Equipment) Regulations (Northern Ireland) 1992 [213]	SR 1992 No. 513	90/270/EEC [212]
Health and Safety (Miscellaneous Amendments) Regulations 2002 [211]	SI 2002 No. 2174	The Regulations give effect to point 19.2 of Annex 2 to 89/654/EEC [214], amend the Health and Safety (Display Screen Equipment) Regulations 1992 [54] so as to give full effect to Articles 4 and 5 of 90/270/EEC [212], amend the Manual Handling Operations Regulations 1992 [25] to give effect to Annex II to 90/269/EEC [215], amend the Personal Protective Equipment at Work Regulations 1992 [24] to give full effect to Articles 4(3), (4), (5) and (8) (general provisions) and, in relation to the addition of regulation 4(4), to Article 5(1) (assessment) of 89/656/EEC [216], amend the Workplace (Health, Safety and Welfare) Regulations 1992 [3] to variously give complete, or clearer, effect to provisions of 89/654/EEC [214], and amend the Provision and Use of Work Equipment Regulations 1998 [13] to give clearer effect to Article 4 of, and point 2.8 of Annex 1 to, 95/63/EC [217] as amended

Table A.1 **Summary of statutory regulations referred to in this British Standard, with details of related EC Directives** *(continued)*

Title	Statutory Instrument (SI) reference	National implementation of EU Directive (where applicable)
Health and Safety (Miscellaneous Amendments) Regulations (Northern Ireland) 2003 [218]	SR 2003 No. 423	The Regulations give effect to point 19.2 of Annex 2 to 89/654/EEC [214], amend the Health and Safety (Display Screen Equipment) Regulations (Northern Ireland) 1992 [213] so as to give full effect to Articles 4 and 5 of 90/270/EEC [212], amend the Manual Handling Operations Regulations (Northern Ireland) 1992 [219] to give effect to Annex II to 90/269/EEC [215], amend the Personal Protective Equipment at Work Regulations (Northern Ireland) 1993 [220] to give full effect to Articles 4(3), (4), (5) and (8) (general provisions) and, in relation to the addition of regulation 4(4), to Article 5(1) (assessment) of 89/656/EEC [216], amend the Workplace (Health, Safety and Welfare) Regulations (Northern Ireland) 1993 [221] to variously give complete, or clearer, effect to provisions of 89/654/EEC [214], and amend the Provision and Use of Work Equipment Regulations (Northern Ireland) 1999 [222] to give clearer effect to Article 4 of, and point 2.8 of Annex 1 to, 95/63/EC [217] as amended
Health and Safety (Safety Signs and Signals) Regulations 1996 [32]	SI 1996 No. 341	92/58/EEC [223]
Health and Safety (Safety Signs and Signals) Regulations (Northern Ireland) 1996 [224]	SR 1996 No. 119	92/58/EEC [223]
Ionising Radiations Regulations 1999 [53]	SI 1999 No. 3232	96/29/Euratom [225], 90/641/Euratom [226] and 97/43/Euratom [227]
Ionising Radiations Regulations (Northern Ireland) 2000 [228]	SR 2000 No. 375	96/29/Euratom [225], 90/641/Euratom [226] and 97/43/Euratom [227]
Large Combustion Plants (England and Wales) Regulations 2002 [74]	SI 2002 No. 2688	2001/80/EC [180] in part
Large Combustion Plants (Scotland) Regulations 2002 [229]	SSI 2002 No. 493	2001/80/EC [180] in part
Large Combustion Plants Regulations (Northern Ireland) 2003 [230]	SR 2003 No. 210	2001/80/EC [180] in part
Lifting Operations and Lifting Equipment Regulations 1998 [28], as amended by the Health and Safety (Miscellaneous Amendments) Regulations 2002 [211]	SI 1998 No.2307	89/655/EEC [231] and 95/63/EC [217] with respect to lifting equipment

Table A.1 **Summary of statutory regulations referred to in this British Standard, with details of related EC Directives** *(continued)*

Title	Statutory Instrument (SI) reference	National implementation of EU Directive (where applicable)
Lifting Operations and Lifting Equipment Regulations (Northern Ireland) 1999 [232], as amended by the Health and Safety (Miscellaneous Amendments) Regulations (Northern Ireland) 2003 [218]	SR 1999 No. 304	89/655/EEC [231] and 95/63/EC [217] with respect to lifting equipment
Management of Health and Safety at Work Regulations 1999 [2]	SI 1999 No. 3242	The Regulations implement 89/391/EEC [233] and 91/383/EEC [234] with some exceptions, Articles 4 to 7 of 92/85/EEC [235], Article 6(2) (a)–(i) of 89/391/EEC [233], amend the Mines Miscellaneous Health and Safety Provisions Regulations 1995 [236] so as to give full effect to Articles 8(1) and 8(2) 89/391/EEC [233], and amend the Construction (Health, Safety and Welfare) Regulations 1996 [237] so as to give full effect to Article 8(1) and 8(2) of 89/391/EEC [236]
Management of Health and Safety at Work Regulations (Northern Ireland) 2000 [238]	SR 2000 No. 338	—
Management of Health and Safety at Work and Fire Precautions (Workplace) (Amendment) Regulations 2003 [239]	SI 2003 No. 2457	98/24/EC [136], so far as that Directive relates to safety, and 1999/92/EC [167]
Management of Health and Safety at Work and Fire Precautions (Workplace) (Amendment) Regulations (Northern Ireland) 2003 [240]	SR 2003 No. 454	98/24/EC [136], so far as that Directive relates to safety, and 1999/92/EC [167]
Management of Health and Safety at Work (Amendment) Regulations 2006 [241]	SI 2006 No. 438	—
Management of Health and Safety at Work (Amendment) Regulations (Northern Ireland) 2006 [242]	SR 2006 No. 255	—
Manual Handling Operations Regulations 1992 [25], as amended by the Health and Safety (Miscellaneous Amendments) Regulations 2002 [211]	SI 1992 No. 2793	90/269/EEC [215]
Manual Handling Operations Regulations (Northern Ireland) 1992 [243], as amended by the Health and Safety (Miscellaneous Amendments) Regulations (Northern Ireland) 2003 [218]	S.R. 1992 No. 535	90/269/EEC [215]

Table A.1 **Summary of statutory regulations referred to in this British Standard, with details of related EC Directives** *(continued)*

Title	**Statutory Instrument (SI) reference**	**National implementation of EU Directive (where applicable)**
Personal Protective Equipment at Work Regulations 1992 [24], as amended by the Health and Safety (Miscellaneous Amendments) Regulations 2002 [211]	SI 2002 No. 1144	89/686/EEC [244] as amended by 93/95/EEC [245], 93/68/EEC [169] and 96/58/EC [246]
Personal Protective Equipment at Work Regulations (Northern Ireland) 1993 [220], as amended by the Health and Safety (Miscellaneous Amendments) Regulations (Northern Ireland) 2003 [218]	SR 1993 No. 20	89/686/EEC [244] as amended by 93/95/EEC [245], 93/68/EEC [169] and 96/58/EC [246]
Pipelines Safety Regulations 1996 [96]	SI 1996 No. 825	—
Pollution Prevention and Control (England and Wales) Regulations 2000 [60]	SI 2000 No. 1973	96/61/EC [175]
Pollution Prevention and Control (Scotland) Regulations 2000 [247]	SSI 2000 No. 323	96/61/EC [175]
Pollution Prevention and Control Regulations (Northern Ireland) 2003 [248], as amended by the Pollution Prevention and Control (Amendment) Regulations (Northern Ireland) 2007 [249]	SR 2003 No. 46 as amended by SR 2007 No. 245	96/61/EC [175]
Pressure Equipment Regulations 1999 [18]	SI 1999 No. 2001	97/23/EC [98]
Pressure Equipment (Amendment) Regulations 2002 [250]	SI 2002 No. 1267	Amends SI 1999 No. 2001 to correctly implement 97/23/EC [98]
Pressure Systems Safety Regulations 2000 [45]	SI 2000 No. 128	—
Pressure Systems Safety Regulations (Northern Ireland) 2004 [251]	SR 2004 No. 222	—
Provision and Use of Work Equipment Regulations 1998 [13], as amended by the Health and Safety (Miscellaneous Amendments) Regulations 2002 [211]	SI 1998 No. 2306	89/655/EEC [230] and 95/63/EC [217]

Table A.1 **Summary of statutory regulations referred to in this British Standard, with details of related EC Directives** *(continued)*

Title	Statutory Instrument (SI) reference	National implementation of EU Directive (where applicable)
Provision and Use of Work Equipment Regulations (Northern Ireland) 1999 [222], as amended by the Health and Safety (Miscellaneous Amendments) Regulations (Northern Ireland) 2003 [218]	SR 1999 No. 305	89/655/EEC [230] and 95/63/EC [217]
Radio Equipment and Telecommunications Terminal Equipment Regulations 2000 [20]	SI 2000 No.730	1999/5/EC [252]
Radio Equipment and Telecommunications Terminal Equipment (Amendment) Regulations 2003 [253]	SI 2003 No.1903	1999/5/EC [252] as amended by 2004/108/EC [171]
Radio Equipment and Telecommunications Terminal Equipment (Amendment No. 2) Regulations 2003 [254]	SI 2003 No. 3144	—
Reporting of Injuries, Diseases and Dangerous Occurrences Regulations 1995 [9]	SI 1995 No. 3163	—
Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment Regulations 2008 [86]	SI 2008 No. 37	—
Supply of Machinery (Safety) Regulations 1992 [17]	SI 1992 No. 3073	98/37/EC [255] Previously Directive 89/392/EEC [256] as amended by Directives 91/368/EEC [257] and 93/68/EEC [169]. The original Directive and its amendments have been consolidated in the single Directive 98/37/EC.
Supply of Machinery (Safety) (Amendment) Regulations 1994 [258]	SI 1994 No. 2063	93/44/EEC [259]
Supply of Machinery (Safety) (Amendment) Regulations 2005 [260]	SI 2005 No. 831	98/37/EC [255]
Supply of Machinery (Safety) Regulations 2008 [97] (with effect from December 2009)	SI 2008 No. 1597	2006/42/EC [261]
Waste Electrical and Electronic Equipment Regulations 2006 [83]	SI 2006 No. 3289	2002/96/EC [181] as amended by 2003/108/EC [262]

Table A.1 **Summary of statutory regulations referred to in this British Standard, with details of related EC Directives** *(continued)*

Title	Statutory Instrument (SI) reference	National implementation of EU Directive (where applicable)
Waste Incineration (England and Wales) Regulations 2002 [75]	SI 2002 No. 2980	2000/76/EC [179] in part
Waste Incineration (Scotland) Regulations 2003 [263]	SSI 2003 No. 170	2000/76/EC [179] in part
Waste Incineration Regulations (Northern Ireland) 2003 [264]	SR 2003 No. 390	2000/76/EC [179]
Workplace (Health, Safety and Welfare) Regulations 1992 [3], as amended by the Health and Safety (Miscellaneous Amendments) Regulations 2002 [211]	SI 1992 No. 3004	89/654/EEC [214]
Workplace (Health, Safety and Welfare) Regulations (Northern Ireland) 1993 [221], as amended by the Health and Safety (Miscellaneous Amendments) Regulations (Northern Ireland) 2003 [218]	SR 1993 No. 37	89/654/EEC [214]
Work at Height Regulations 2005 [30]	SI 2005 No. 735	2001/45/EC [265] amending 89/655/EEC [231]
Work at Height Regulations (Northern Ireland) 2005 [266]	SR 2005 No. 279	2001/45/EC [265] amending 89/655/EEC [231] and 92/57/EEC [128]
Work at Height (Amendment) Regulations (Northern Ireland) 2007 [267]	SR 2007 No. 135	2001/45/EC [265] amending 89/655/EEC [231] and 92/57/EEC [128]
Work at Height (Amendment) Regulations 2007 [268]	SI 2007 No. 114	2001/45/EC [265] amending 89/655/EEC [231] and including additional provisions which replace regulations giving effect to certain provisions of 89/654/EEC [213] concerning the minimum safety and health requirements for the workplace and 92/57/EEC [128] on the implementation of minimum safety and health requirements at temporary or mobile construction sites

Annex B (informative) List of test and calibration equipment

The following is an example of test and calibration equipment which might be required for on-site instrument testing and pre-commissioning.

This list is not exhaustive and the requirements for a specific project will need to be reviewed on a case-by-case basis.

a) *Pressure test and calibration equipment.*

The following equipment might be required:

1) manual pump suitable to achieve maximum required test pressures;
2) bottles gas or air at pressure adequate to achieve maximum test pressures;
3) dead-weight tester;
4) pressure gauge comparison test pump;
5) precision air filter/regulator sets (two sets minimum);
6) liquid filled manometers suitable for test pressure range;
7) electronic pressure gauge suitable for test pressure range;
8) certified test gauges, 0.25% accuracy or better;
9) portable pneumatic calibration boxes (two boxes minimum);
10) portable air compressor (where air is not available).

NOTE 1 All test instruments need to be provided with test leads complete with test probes, clips and distribution terminals.

b) *Temperature test and calibration equipment*.

The following equipment might be required:

1) thermostatically controlled temperature bath(s);
2) thermostatically controlled oven for checking cold junction compensation;
3) sets of standard (precision) glass thermometers;
4) electronic temperature sensor;
5) precision potentiometer and millivolt generator;
6) precision Wheatstone bridge incorporating a detachable resistance box where resistance thermometers are to be installed, accurate to 0.05% on any resistance value;
7) decade resistance box accurate to 0.1%.

c) *General electronic/electrical test and calibration equipment*.

The following equipment might be required:

1) digital voltmeters (a minimum of two, portable) with an accuracy of 0.1% of range or better and with a discrimination of 10 μV or better, and incorporating an internal calibration/standardizing feature and 0.1% calibration resistors;
2) precision millivolt, volt and milliamp source measuring device;
3) portable multimeters;
4) insulation resistance testers;
5) stop-watch and relay contact timing device;
6) dual-beam oscilloscope;
7) frequency/pulse generator.

d) *Instrument manufacturer calibration and test equipment*.

The following equipment might be required:

NOTE 2 The use of these is recommended to simplify connections and signal compatibility;

1) for specific instruments and systems the manufacturers often provide dedicated calibration or test equipment which can include any combination of the devices in a), b) and c);
2) for many microprocessor-based "smart" instruments, hand-held calibrators, programmers or communicators are available to ensure proper setting of the instruments.

e) *Laptop*.

Laptops computers may be employed as follows:

1) work management and records capture – work instructions to undertake test procedures along with records of test results may be issued and stored through electronic media;
2) configuration and calibration software.

For many transmitters, software for configuration and calibration is available for use via a laptop.

Annex C (informative) Guidance on information to be included on calibration and commissioning documentation

C.1 General

Instrumentation and control systems need to be thoroughly inspected, calibrated and commissioned before they can be considered as operational. Such inspection and tests need to be recorded to demonstrate that the installation is safe and fit for purpose. Records were traditionally paper-based but increasingly electronic recording systems are being employed.

This annex provides guidance on the information required to complete documentation, but the specific circumstances of any installation need to be taken into account when drafting the appropriate calibration and commissioning sheets.

C.2 General information

All records need to capture the following data:

- purpose of the record (inspection, calibration, testing or commissioning);
- date;
- location;
- equipment details including:
  - function (e.g. type of transmitter/control system);
  - duty (purpose of equipment);
  - designation (e.g. manufacturer, model, serial number, tag);
  - calibrated range;
  - settings;
  - details of individual carrying out work;
  - details of individual checking work/records.

Depending on the type of installation and function of the documentation, the following information will also be required.

C.3 Inspection

Inspections are needed to confirm that the installation conforms to the installation's design criteria. As such the following information needs to be captured:

- sections covering separate elements of the installation such as pipework, equipment, equipment connections and cabling;
- qualitative observations for each element of the installation detailing conditions, suitability and standard of work. Deviations from acceptable standards need to be clearly identified.

An example of an instrument pre-installation calibration check sheet is shown in Figure C.1.

An example of an instrument loop check sheet is shown in Figure C.2.

Figure C.1 **Example of instrument pre-installation calibration check sheet**

INSTRUMENT PRE-INSTALLATION CALIBRATION SHEET

CLIENT: PLANT:

CLIENT'S PROJECT No.: PROJECT No.:

INST. TAG No: SERVICE:

TYPE: MODEL No.: SERIAL No.:

MANUFACTURER: ORDER No.: SPEC. No.:

SIGNAL RANGE: DIAL/CHARTRANGE:

PHYSICAL CHECK:

PROCESS CONN. CORECT		PNEU./ CONN. CORRECT	
BODY MATERIAL CORRECT		RANGE/SPAN CORRECT	
ELECT. SUPPLY SETTING CORRECT		AIR SUPPLY SETTING CORRECT	
GENERAL CONDITION SATISFACTORY		ANCILLIARY EQUIPMENT SUPPLIED	

SHIPPING STOPS REMOVED ☐

CALIBRATION CHECK:

	INPUT		READING OR OUTPUT					
	% SPAN	ACTUAL	RISING			FALLING		
MAKER'S	0		ACTUAL	% SPAN	ERROR%	ACTUAL	% SPAN	ERROR%
QUOTED	25							
ACCURACY	75							
	100							

CONTROLLER CHECK: CONTROL MODE-PROPORTIONAL ☐ INTEGRAL ☐ DERIVATIVE ☐

ON-QFF ☐ DIFF. GAP ☐

CONTROLLER ALIGNMENT CORRECT ☐ AUTO/MANUAL CORRECT ☐

SETTINGS CONTROL ACTION DIRECT ☐ REVERSE ☐ DIFF.GAP_______%

ALARM SETTING __________________________ TIME DELAY SETTING ____________________

LIMIT SWITCH SETTING – HIGH _____________ LOW ____________________________________

OUTPUT LIMIT SETTING – HIGH _____________ LOW ____________________________________

CORRECTIONS: AUTOMATIC TEMPERATURE CORRECTION RANGE _____________________________

S.G./DENSITY CORRECTION SETTING _____________________________________

ZERO ELEVATION/SUPPRESSIDN SETTING ____

THERMO-COUPLE BURNOUT DRIVES UPSCALE ☐ DOWNSCALE ☐

SHIPPING STOPS REFITTED ☐

ANCILLIARY EQUIPMENT LIST:

REMARKS:

CHECKED BY:	DATE:	WITNESSED BY:	DATE:
ACCEPTED BY:		FOR:	DATE:
*		INSTRUMENT TAG NO.	

Figure C.2 **Example of instrument loop check sheet**

INSTRUMENT LOOP CHECK SHEET

CLIENT:			PLANT:	
CLIENT'S PROJECT No.:			PROJECT No.:	
LOOP No. ______			SERVICE ______	
LINE OR EQUIPMENT No.			PIPEI.D.	
MECHANICAL ELECTRICAL CHECKS				
MEASURING ELEMENT:	INSTALLATION CORRECT.	☐	LOCATION CORRECT	☐
	ISOLATING VALVES CORRECT	☐	MATERIALS CORRECT	☐
	TAPPING (S) POSITION CORRECT	☐	ORIFICE DIAMETER ______	
IMPULSE CONNECTIONS:	CORRECT TO HOOK.UP	☐	MATERIALS CORRECT	☐
	PRESSURE TESTED	☐	TEST PRESSURE ______	
	STEAM/ELECT. TRACED	☐	LAGGED	☐
FIELD INSTRUMENT(S)	INSTALLATION CORRECT	☐	AIR SUPPLY CORRECT	☐
	WEATHER PROTECTED	☐	POWER SUPPLY CORRECT	☐
PANEL INSTRUMENT(S)	INSTALLATION CORRECT	☐	AIR SUPPLY CORRECT	☐
	SCALE/CHART CORRECT	☐	POWER SUPPLY CORRECT	☐
CONTROL VALVE	INSTALLATION" LOCATION CORRECT	☐	SIZE 8. TYPE CORRECT	☐
	STROKE TESTED	☐	POSITIONER CHECKED	☐
	LIMIT SWITCHES SET	☐	I./P. TRANSDUCER CHECKED	☐
AIR SUPPLIES	CONNS. CORRECT TO DWGS.	☐	BLOWN CLEAR &. LEAK TESTED	☐
TRANSMISSION. PNEU:	LINES INSPECTED, BLOWN CLEAR LEAK TESTED		☐	
TRANSMISSION. ELECT.	INSULATION CHECKED-CORE TO CORE	☐	CORE TO EARTH	☐
	CONTINUITY CHECKED	☐	LOOP IMPEDANCE CHECKED	☐
	EARTH BONDING CHECKED	☐	ZENER BARRIERS CORRECT	☐
TEMPERATURE LOOPS:	T/CORR/BCHECKED	☐	CABLE TO SPECIFICATION	☐
	CONTINUITY CHECKED	☐	LOOP IMPEDANCE CHECKED	☐
GENERAL:	SUPPORTS CORRECT	☐	TAGGING CORRECT	☐
CHECKED BY:	DATE: WITNESSED BY:		DATE	

LOOP TEST:

	TRANSMITTER INPUT	TRANSMITTER OUTPUT	LOCAL INST. READING	PANEL INST READING	
MEASUREMENT					
	CONTROLLER OUTPUT	**TRANSDUCER OUTPUT**	**VALVE POS'NR OUTPUT**	**CONTROL VALVE POSITION**	
CONTROL					

REMARKS: ______

______

CHECKED BY:	DATE:	WITNESSED BY:	DATE:
ACCEPTED BY:		FOR:	DATE:
*		INSTRUMENT LOOP NO.	

C.4 Calibration

Calibration of equipment is needed to demonstrate that where measurements are made, they are to acceptable uncertainties. Documentation needs to reflect the requirements as specified in the calibration procedures. As such the following information needs to be captured:

- statement of the maximum acceptable uncertainty;
- details of the test equipment used, including its calibration date, uncertainty and traceable calibration standard;
- testing over the full operational range of an instrument or control system;
- for switches, details of activation settings, and process variable reading at activation. The deviation between setting and activation may be noted separately for clarity;
- for instrumentation, details of the actual process variable applied and the instrument reading. The deviation between applied variable and reading may be noted separately for clarity. Depending on the type of instrument tests, it might be necessary to demonstrate error due to hysteresis by taking rising and lowering readings;
- for control systems, additional information relating to the output of the system will be required;
- for safety systems, demonstration of correct operation as specified;
- fail or pass calibration statement.

Where corrective action to rectify calibration errors is acceptable then records need to identify the action taken, and a second calibration record is needed to clearly identify the distinction between as-found and as-left calibration results.

An example of a pressure indicator calibration check sheet is shown in Figure C.3.

The instrument pre-installation calibration check sheet shown in Figure C.1 can be used for any further calibrations required, with its title changed to reflect the purpose of the calibration.

C.5 Testing

Testing of systems is needed to demonstrate correct operation. Documentation needs to reflect the requirements as specified in operational procedures.

Testing is intended to demonstrate the following:

- correct operation and functionality of systems;
- for switches, operation and resulting control actions;
- for transmitters, control actions resulting for changes in measured parameters;
- for control systems, control output with respect to control parameters and system inputs;
- failure modes;
- observation of expected and unexpected events;
- correct operation of safety systems.

Test documentation needs to be written with reference to the system under test, and to include the following details:

- equipment or system under test;
- purpose of test;
- test procedure;
- outcome of test;
- pass/fail criteria.

An example of an alarm system check sheet is shown in Figure C.4.

An example of a pressure relief valve test report is shown in Figure C.5.

Figure C.3 **Example of pressure indicator calibration check sheet**

CALIBRATION CHECK SHEET					PRESSURE GAUGES *				
CLIENT: CLIENT'S PROJECT NO:					PLANT: PROJECT NO:				
TAG No.	RANGE	CHECKED	WITNESS	DATE	TAG No.	RANGE	CHECKED	WITNESS	DATE
* DELETE AS APPLICABLE.									
					PI/* CHECK SHEET SHEET No.				

Figure C.4 **Example of alarm system check sheet**

ALARM SYSTEM CHECK SHEET

CLIENT: PLANT:

CLIENT'S PROJECT No.: PROJECT No.:

INST. TAG No:___________________________ LOCATION:____

ANNUNCIATION TYPE __________ SIZE:_______________________ SERIAL No._____________________

MANUFACTURE _______________ ORDER No. _________________ SPEC. No._______________________

GENERAL CHECK:

GENERAL CONDITION SATISFACTORY	☐	AUDIBLE ALARM OPERATES	☐
ENGRAVING CORRECT TO SPEC.	☐	ACK. & TEST BUTTONS OPERATE	☐
ELECT. SUPPLY SETTING CORRECT	☐		☐
ALARM SEQUENCE CORRECT	☐		☐

ALARM LOOP CHECK

		ALARM ACTUATOR CHECK					
POINT No.	ALARM No.	TAG No.	DESCRIPTION	ALARM SETTING	OPERATION CORRECT	INSTALL'N CORRECT	ALARM OPERATION CORRECT

REMARKS:

CHECKED BY:	DATE:	WITNESSED BY:	DATE:
ACCEPTED BY:		FOR:	DATE:
*		ALARM SYSTEM NO.	

Figure C.5 **Example of pressure relief valve test report**

PRESSURE RELIEF VALVE – TEST REPORT

CLIENT: PLANT:

CLIENT'S PROJECT No.: PROJECT No.:

VALVE DATA

TAG No. SERVICE

TYPE: MODEL No.: SERIAL No.:

MANUFACTURER: ORDER No.: SPEC. No.:

INLET SIZE: OUTLET SIZE: ORIFICE SIZE:

OPERATING DATA

SET PRESSURE: BACK PRESSURE:

SPRING SET PRESSURE: OPERATING TEMP.:

PHYSICAL CHECK

BODY MATERIAL CORRECT:	☐	LIFTING LEVER -OPEN:	☐
CONNECTIONS CORRECT:	☐	PACKED:	☐
SPRING MATERIAL CORRECT:	☐	SCREWED CAP:	☐
NOZZLE MATERIAL CORRECT:	☐	TEST GAG:	☐
DISC MATERIAL CORRECT:	☐	LOCKING DEVICE:	☐
BELLOWS MATERIAL CORRECT:	☐		

TEST RESULTS	UNITS	SPECIFIED VALUE	TEST RESULT	REMARKS
COLD SPRING SET PRESS.				
RESEAT PRESSURE				
SEAT LEAKAGE RATE (ANSI BI47.1(API527))				

GENERAL REMARKS

CHECKED BY: DATE: WITNESSED BY: DATE:

ACCEPTED BY: FOR: DATE:

* SAFETY RELIEF VALVE TEST REPORT No.:

C.6 Commissioning

Commissioning represents a confirmation that equipment is safe and fit for purpose and that handover to the operator/owner has taken place. Documentation needs to reflect the requirements as specified in the commissioning procedures. The following information might be required:

- reference to documented commissioning procedures;
- reference to inspection and calibration documentation;
- demonstration of compliance with appropriate recommendations/requirements;
- demonstration of the operation of installed equipment;
- formal acceptance by site equipment operator/owner or their representative.

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